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Pol. Suec. Dannebrog Dan. S. Srum. Maur. et Lazar. Ital.

Tol. Suec. Dannebrog. Dan. S. Frum. Maur. et Lazar. Ital.
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To Dr. Senft of Eisenach
from his obliged friend
Ferd. Hillmer Nielsen

SILURIA.

THE

HISTORY OF THE OLDEST FOSSILIFEROUS ROCKS

AND THEIR FOUNDATIONS;

WITH A BRIEF SKETCH OF

THE DISTRIBUTION OF GOLD OVER THE EARTH.

BY

SIR RODERICK IMPEY MURCHISON,

G.C.St.S.; D.C.L.; M.A.; V.P.R.S.; V.P.G.S.; F.L.S.; H.M.R.S.Ed.; R.I.Ac.;

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THIRD EDITION,

(*Including "The Silurian System,"*)

WITH MAPS AND MANY ADDITIONAL ILLUSTRATIONS.

"The men who begin with speculation and end with facts begin at the wrong end; the firmest materials should be in the foundations; . . ."—*Sir H. Davy.*

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

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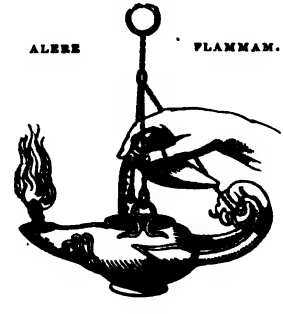

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Dedication.

TO MY FRIENDS

EDOUARD DE VERNEUIL,

ALEXANDER VON KEYSERLING,

AND

JOACHIM BARRANDE,

I GRATEFULLY DEDICATE THIS NEW EDITION OF

SILURIA.

THE last Edition of this Work having been inscribed to the late SIR HENRY DE LA BECHE, *who, with his associates in the Geological Survey, adopted the Silurian Classification for Britain, the present volume is dedicated to the men whose arduous researches and philosophical writings have spread that classification through Foreign Countries.*

M. DE VERNEUIL *and* COUNT KEYSERLING *are requested to*

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accept this token of my regard, in remembrance of our labours when we explored together the RUSSIAN EMPIRE; *the first having since applied our views in* FRANCE, SPAIN, *and* AMERICA,—*the last having extended them northwards to* PETCHORA-LAND.

With these valued companions is associated the enlightened Paleontologist M. BARRANDE, *who has shown, on the clearest evidence, that in the heart of* GERMANY, *as elsewhere, the Lower and Upper Silurian deposits constitute one great natural system.*

RODERICK IMPEY MURCHISON.

Belgrave Square, London,
Dec. 31st, 1858.

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PREFACE TO THIS EDITION.

THE chief object of this work is to show the nature of the foundation-stones of Geological History as now known to us by their imbedded organic remains; and the geological reader into whose hands it may fall, will find that, while sustaining the same general views which were published in the last edition, it contains very numerous additions as respects both Britain and Foreign Countries.

If a work relating to the history of Man be founded upon the best authorities, slight alterations are alone looked for in a new edition. Very different, however, is the responsibility of the geologist, who, eliciting from time to time many new truths from the repositories of ancient Nature, must bring before the public each freshly discovered fact which may influence his conclusions.

In the first place, then, a most important section, exhibiting the lowest rocks in the British Isles, as lying beneath all the oldest known sedimentary and fossiliferous rocks, is described in the opening Chapter, —the coloured Frontispiece displaying at one view a lower succession of the fundamental rocks of our country than was previously known,— those rocks being unconformably surmounted by crystalline rocks with Lower Silurian fossils.

It is true that in the year 1851, and again in 1854 (see previous edition, p. 162), I speculated on the possibility of a large portion of the crystalline stratified rocks of the Highlands proving to be the equivalents of the Lower Silurian of the southern part of Scotland; but it was not until 1855 that I saw indications of the correctness of that hypothesis, by the discovery of a few imperfect fossils by Mr. C. Peach in the limestones of the west of Sutherland. Encouraged by me to proceed in his inquiries, that able explorer has detected so many recognizable species, that, after revisiting the localities, accompanied by him, during this year, I am completely satisfied that the opinions I formerly announced to the Geological Society are substantially correct.

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It now transpires, that the gneiss of the N.W. coast of the Highlands is *older than any rock of England or Wales*,—being surmounted by strata the equivalents of which in England constitute the Cambrian rocks, and which, formerly mistaken for Old Red Sandstone, are in their turn overlapped most clearly by quartz rocks with limestones, the fossils of which prove them to be of Lower Silurian age. Other overlying rocks (mica-schists, &c.) follow, all dipping to the E.S.E.; whilst the true Old Red Sandstone of the east coast of Scotland is shown to be compounded out of all these pre-existing rocks.

In the following chapters eighty-four additional fossils are figured in woodcuts, many of them being new species. The naturalist who calls for more elaborate descriptions of these new forms than are here offered, must for a brief time be satisfied with the small and sharply defined drawings prepared under the eye of Mr. Salter, whose assistance and advice have been of paramount value to me throughout, and who in other works will give detailed descriptions which are incompatible with my present object.

One of the chief deficiencies in the preceding edition of this work was the omission of the original beautiful plates of Corals of the Silurian rocks, both Lower and Upper, admirably drawn by Mr. Scharf, sen., under the direction of my eminent friend Mr. W. Lonsdale, who described these fossils. The lithographic drawings, which were supposed to have been rubbed off the stones, having been fortunately preserved, these highly characteristic plates (38 to 41 inclusive) doubtlessly add much value to the present volume.

Besides the identification of the Bala rocks and fossils with those of the Caradoc formation, various improvements will be found in the annexed Map; one of these being the introduction of an intermediate zone of rocks which connects the Lower and Upper Silurian, under the name of the "Llandovery Rocks." To render this subject more clear, a chapter is devoted to it, and the fossils specially characteristic of the middle and connecting zone are removed from the old Plates of the Caradoc Sandstone and grouped by themselves, in accordance with conclusions at which I arrived in the year 1856, not only on paleontological grounds, but also by physical evidences obtained in company with Professor Ramsay and Mr. Aveline, when we resurveyed many parts of the original Silurian region. Let me here say, however, that, excepting this modification, the Silurian classification remains precisely such as it was when sanctioned by my predecessor, Sir H. De la Beche, and his associates.

In respect to the Devonian or Old Red rocks, great improvements of classification have, it is hoped, been made. Thus, it is now clearly demonstrated by sections along the original Silurian frontier, that the zone containing Cephalaspis and Pteraspis is the real base of this group,

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and that this band passes downwards regularly and gradually into the uppermost Silurian rock. Hence it follows, that the Caithness flagstones and their extensions in Ross and Moray, which are charged with ichthyolites very different from those of the Cephalaspis zone of England and Forfarshire, and repose upon a great thickness of red sandstone conglomerate, can no longer be considered as the lower band, but manifestly constitute the middle zone of the Old Red or Devonian group. Again, some interesting new matter is produced (pp. 558, 570) touching the uppermost Devonian zone in Scotland, and the existence in it of a large reptile (the Stagonolepis), in addition to the little Telerpeton Elginense.

The body of this work has, further, been much improved by the accession of new data derived from many foreign sources. On this head, the reader will not fail to see the value of the contributions from the labours of de Verneuil in France and Spain, of Barrande in Bohemia, of Kjerulf in Norway, and of von Keyserling and Schmidt in the Baltic provinces of Russia. He will further find, that the true fossiliferous base of the Silurian rocks in Norway, Sweden, and France, as well as in England and N. America, is the zone of Lingula Flags.

The reader will also observe, that my acquaintance with the Permian rocks has been considerably enlarged by personal examination in the years 1854–7 of many tracts which have long been classical among German geologists; and I trust that the truthfulness of the classification which I proposed in 1841 under the name of "Permian" will now be completely established by clear proofs, both stratigraphical and paleontological (the botanical evidences being obtained not only from Gutbier and Geinitz, in Saxony, but largely from Göppert, of Breslau), showing that the Roth-todt-liegendes, or Lower New Red Sandstone of English geologists, is really the base of that supra-Carboniferous group.

It may further be stated, that this volume has been enriched by several Tables, which are the result of much close labour and knowledge. The first of these (p. 157) is a Diagram prepared by Mr. Talbot Aveline, to represent in parallel vertical columns the order and dimensions of the Silurian rocks in those parts of England and Wales with which he is thoroughly acquainted, and the lines of which he has laid down with so much ability on the maps of the Government Survey. The next is a Table of the Upper Paleozoic rocks (pp. 432, 433), in which I have endeavoured to show the equivalents of the Devonian, Carboniferous, and Permian rocks in the different parts of Europe; and a third (pp. 472, 473) is a general tabular view of the North American Paleozoic rocks, as prepared by Professor Ramsay since his recent visit to Canada and the United States. The fourth Table is very elaborate and detailed (see Appendix A.); and in it Mr. Salter, aided by Prof. Morris, has exhibited, in seven separate columns, the vertical range

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whilst I write these lines.
to Mr. T. Rupert Jones, who
Germany, for his continuous aid
; to the Rev. W. Symonds, of
compiling the Index of 'Siluria';
panied me in two foreign tours in
kind friends whose names appear

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[illegible] of the British Silurian fauna,— [illegible] have so well accomplished. By [illegible] from foreign researches, it [illegible] appear to have a closely defined [illegible] or ascend into higher or [illegible] closely the Lower [illegible]*

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[illegible] with the slaty rocks of the [illegible] Wales was long ago demonstrated, not by me, but by [illegible] when the Welsh rocks and fossils which had not been [illegible] in 1838 with the then published types of the Silurian region, were found to be mere western extensions of those types, the names of Lower and Upper Silurian were applied to them by my contemporaries

* A similar work has been [illegible] Silurian fossils of the State [illegible] The published works of [illegible] American geologists are the [illegible] used, and the data have been [illegible] with care and judgment.

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of the Geological Survey at home, and, in reference to such rocks, have passed into general use in foreign countries. Eschewing, however, all controversy upon the vexed question of nomenclature, on which my eminent friend and myself have fully explained our respective views, I would simply refer to the Introductory Chapter for a brief account of the publications of various authors relating to discoveries in the Silurian region.

I cannot, however, close this Preface without reiterating the very deep sense I entertain of the valuable assistance I received during my earliest labours from my excellent and kind friend the late Rev. T. T. Lewis, of Aymestry, whose acquaintance with the true order of the rocks in the environs of Ludlow, as worked out by himself, was most serviceable in enabling me to establish the correct order of the Upper Silurian rocks, and whose death, alas! I have to deplore whilst I write these lines.

Lastly, let me record my grateful thanks to Mr. T. Rupert Jones, who was my companion in my last visit to Germany, for his continuous aid in passing this volume through the press; to the Rev. W. Symonds, of Pendock, near Ledbury, for again ably compiling the Index of 'Siluria'; to Professor John Morris, who accompanied me in two foreign tours in 1853 and 1854; and to various other kind friends whose names appear in the sequel.

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ERRATA AND CORRIGENDA.

Page
32, heading, *for* 23 *read* 32.
41, heading, *for* 14 *read* 41.
47, expl. of woodcut, *for* Graptopora *read* Dictyonema; also l. 17 (see Table, p. 541).
50, expl. of woodcut, *for* Redonia *read* Ribeiria; and l. 15, *for* Redonia or, *read* Ribeiria and.
80, l. 8 from bottom, *et passim*, *for* Strophomena spiriferoides *read* Orthis spiriferoides.
80 and 81, *for* Glyptocystites *read* Pleurocystites.
97, l. 25, *for* Chap. 8 *read* Chap. 9.
101, l. 2, 3, *omit* Bumastus Barriensis, Phacops Downingiæ, Goniophora cymbæformis. These fossils do not occur in the Llandovery rocks. (See Table, p. 532.)
106, l. 21, *after* Foss. 7. f. 5. *add*, *supra*, p. 74, Foss. 12. f. 5.
155, l. 5, 8, also expl. of cut, *for* P. Anglicus *read* P. Ludensis.
163, l. 18, *for* has discovered to be the equivalent of the Caradoc, *read* believes to be the equivalent of the May Hill sandstone.
166, l. 10 from bottom, *for* Dyfe *read* Dryfe.
168, expl. of woodcut, *for* sternal *read* caudal.
178, l. 6 from bottom, *for* Pt. lanceolatus *read* Eurypterus lanceolatus.
181, l. 2, *for* resting on ancient gneiss *read*, resting on Cambrian rocks and ancient gneiss.
198, woodcut, *for* Coul-beg *read* Canisp.
207, l. 8, 12, &c., *for* Caryocystites *read* Echinosphærites and Sphæronites. (See App. A.)
216, last 6 lines. For Mr. Woodward's present opinion *see* his Manual of the Mollusca, p. 202.

Page
246, bottom, *for* Cyathocrinus tuberculatus, C. tesseracontadactylus, C. Orbignyi, *read* Taxocrinus. (See Appendix, p. 536.)
256, l. 6 from bottom, *for* Turbo undifer *read* Cyclonema undifera.
265, l. 9 from bottom, *after* Old Red Formations *insert* at Kington, while in beds a little higher at Ludlow, and at Kidderminster, P. Ludensis is the prevailing species.
274, l. 19, *for* Pterygotus gigas *read* P. Ludensis.
276, l. 22, *for* to be identical, *read* not to be identical.
433, l. 6 from bottom, column 4, *for* linear *read* land.
436, expl. of woodcut, l. 6, *for* Cheirurus *read* Placoparia.
445, l. 1, *for* from Almaden on the south to Cordova on the north, *read* from Almaden on the north to Cordova on the south.
473, l. 11, *for* increbrescens *read* increbescens.
523, l. 9, *for* storey *read* story.

Explanations, Pl. V., l. 6 from bottom, *for* Caradoc, Llandeilo, &c. in Llandeilo flags, *read* Caradoc sandstone and Llandeilo flags.
„ Pl. VII. l. 7, *for* Nucula *read* Ctenodonta.
„ Pl. XII. l. 8, *for* shell *read* shells, &c.; *omit* last 3 lines relating to the position of Cophinus dubius, these having been erroneously inserted. The plate is correct. (Salter.)
„ Pl. XIII., *for* Actinoceras *read* Actinocrinus.
„ Pl. XX. l. 15, *for* Darmington *read* Dormington.

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SILURIA.

CHAPTER I.

INTRODUCTION.

A GLANCE AT THE PROBABLE EARLIEST CONDITION OF THE EARTH. — DESIGN OF THIS WORK. — ORIGINAL SILURIAN RESEARCHES AND CLASSIFICATION. — THE FUNDAMENTAL AND PALÆOZOIC ROCKS OF BRITAIN.—RANGE OF THE PALÆOZOIC ROCKS THROUGH OTHER COUNTRIES.

THE earliest condition of the earth is necessarily the least susceptible of investigation. The favourite hypothesis concerning the primary state of the planet, founded on astronomical and physical analogies, is, that it assumed the form of an oblate spheroid from rotation on its axis when in a fluid state. Reasoning upon this idea, and looking to the structure of those rocks which either lie at great depths or have been extruded from beneath, the geologist has inferred that the crystalline masses, including granites, which issued out from below all other rocks, and constitute possibly their existing substratum, were at one time in a molten state. The theory of a central heat, at first sufficiently intense to maintain the whole terrestrial mass in a state of fusion, but subsequently so far dissipated by radiation into space, as to allow the superficial portion to become solid, has been adopted by the greater number of philosophers who have grappled with the difficult problem of the primal state of our planet. Most of them likewise have believed that all the great outbursts of igneous matter, by which the crust has been penetrated and its surface diversified, were merely outward signs of the continued internal activity of the primordial heat, now much repressed

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by the accumulations of ages, and of which our present volcanos are feeble indications. If, then, the mathematician has correctly explained the causes of the shape of the globe, the geologist confirms his views when, examining into the nature of its oldest massive crystalline rocks, he sees in them clear proofs of the effects of intense heat. This original crust of the earth was subsequently, we may believe, broken up by intruded masses, issuing partly at least in a melted condition, and constituting the axes and centres of former mountain-chains very different from those which now exist. Each great igneous eruption gave out substances which became, on cooling, solid rocks; and, when raised into the atmosphere, they constituted lands afterwards exposed to innumerable wasting agencies; thus affording materials to be spread out as deposits upon the shores and bed of the ocean. In these hypothetical views concerning the production of the earliest sediments formed under water, we seem to reach a primary source; and, once admitting that large superficial areas were originally occupied by igneous rocks, we have in them a basis from which the first sedimentary materials may have been obtained.

The earlier eruptions having necessarily occasioned elevations at some points and collapses or depressions at others, such changes of outline, aided by the grinding action of waves, would occasion the formation of bands of sediment, which, adapting themselves to the inequalities of the surface, must have been of unequal dimensions in different parts of their range. In this way we may imagine how, by a repetition of the processes of elevation and denudation, the earliest exterior rugosities of the earth would be in some places increased, while in others they would be placed beyond the influence of sedimentary accumulation. May we not also infer, that the numerous molten masses of great dimensions which were evolved from the interior at subsequent periods must have made enormous additions to the solid crust of the earth, and have constituted grand sources for the augmentation of new strata?

Turning from the igneous rocks to crystalline stratified deposits, we now know that a great portion of the micaceous schists, chloritic and quartzose rocks, clay-slates, and limestones, once called primary, are really of later origin. Many of these are nothing more than subaqueous sediments of various epochs, which have been altered

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and crystallized at periods long subsequent to their accumulation. This inference has been deduced from positive observation. A rock, for example, has been tracked from the districts where it is crystalline, to other spots where the mechanical and subaqueous origin of the beds is obvious, and from the latter to localities where the same stratum is wholly unchanged and contains organic remains. Transitions are thus seen from compact quartz rock, in which the grains of silica are scarcely discoverable even with a lens, to strata in which the sandy, gritty, and pebbly particles bespeak clearly the original accumulation of the mass under water. Equivalent passages occur from crystalline, chloritic, and micaceous schists into those clay-slates which are little more than consolidated mud, and from crystalline marble to common earthy limestone, in which organic remains abound. This kind of metamorphosis comprehends such changes, for example, as those by which ordinary limestone has been converted into dolomite and sulphate of lime or gypsum, also shale into mica-schist, as seen in the secondary and tertiary rocks of the Alps*.

Elementary works, indeed, will have informed the student, that such mutations of the original sediment have been generally accounted for by the supposed influence of great heat proceeding from the interior of the earth, and which at different periods had manifested its power in the eruption of granite, syenite, porphyry, greenstone, basalt, and other substances formed by fusion. Let it, however, be understood, that the prodigious extent to which the metamorphism of the original strata has been carried in mountain-chains, and at various periods through all formations, though often probably connected with such igneous outbursts, must have resulted from a far mightier agency than that which was productive of the mere eruptions of molten matter or igneous rocks. Many of the latter are, in fact, but partial excrescences in the vast spread of the stratified crystalline rocks,—symptoms only of the grander changes which resulted from deep-seated causes; probably from heat and electricity acting upon humid deposits with a powerful intensity.

Processes now going on in nature on a small scale, or imitated artificially by man, may enable us to comprehend imperfectly in

* See Alps, Apennines, &c., Quart. Journ. Geol. Soc. vol. v. p. 157 *et seq.*

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what manner some of these infinitely grander ancient metamorphoses were effected; and experimental chemistry, when more extensively applied to the analysis of rocks, will, it is hoped, some day reveal still more important truths in this very obscure point in the range of geological phenomena.

But speculations on such physical operations are not here called for. At all events, the earliest of the phenomena, which alone have been adverted to in the preceding paragraphs, or the first formation of the known crust of the planet, belongs to a period in which no definite order—still less any trace of life—has been deciphered by human labour*.

The design of this work is much more attainable. Its aim is to mark the most ancient strata in which the proofs of sedimentary or aqueous action are still visible,—to note the geological position of those beds which in various countries offer the oldest ascertained signs of life, and to develope the succession of deposits, where not too much obscured by metamorphism, that belong to such protozoic zones. In thus adhering only to subjects capable of being investigated, it will be seen that Geology, modern as she is among the sciences, has revealed to us, that during immeasurable periods, long anterior to the creation of the human race, and while the surface of the globe was passing from one condition to another, whole races of animals—all the groups adapted to the physical conditions in which they lived—were successively created, lived their appointed time, and perished. It is to the first stages only of these grand accumulations, and to the creatures entombed in them, that attention is now to be directed.

The convictions at which I have arrived being the result of many years of research, I have been induced to give a condensed, and, as far as practicable, a popular view of the oldest sedimentary rocks and of their chief organic remains, and thus to throw into one moderate-sized volume the essence of my larger works†.

* The reader who desires to study the laws by which the superficial temperature of the earth has been regulated in the immensely long subsequent geological periods, will find them well explained in the profound essay of Mr. William Hopkins of Cambridge, "On the causes of changes of climate at different geological periods," Quart. Journ. Geol. Soc. Lond. vol. viii. p. 56.

† See 'Silurian System,' Murchison, 1839; and 'Russia in Europe and the Ural Mountains,' by Murchison, de Verneuil, and de Keyserling; J. Murray, London, 1845. The last gives a view of all geological succession.

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Geologists are now pretty generally agreed, that the oldest well-defined group of organic remains pertains to the lower division of the rocks termed "Silurian"; but before any description of these ancient deposits, or of those preceding them, is given, a few words are required in explanation of the researches by which our acquaintance with the earliest vestiges of life and order in the protozoic world has been attained.

One of the chief steps which led to the present general paleozoic classification, as admitted by my contemporaries, was the establishment of the "Silurian System" of rocks and their imbedded fossils. Before the labours which terminated in the publication of the work so named, no one had unravelled the detailed sequence and characteristic fossils of any strata of a higher antiquity than the Old Red Sandstone; and even that formation was only known to be the natural base of the Carboniferous or Mountain Limestone, and to contain a few fossil fishes. Not only were the relations and contents of all the inferior strata undefined, but even many rocks which are now known to be younger than the Silurian were then considered to be of the most remote antiquity. No one had then surmised, that certain hard slates with fossiliferous limestones and sandstones, which have since been termed Devonian, were equivalents of the Old Red Sandstone, and younger than, as well as distinct from, the deposits of the still older Silurian era. On the contrary, British authorities believed (and I was myself so taught) that the schistose and subcrystalline rocks of Devonshire and Cornwall (most of which are now proved to be of a much more modern date) were about the most ancient of the vast undigested heaps of greywacke. In short, the best geologists* of my early days were accustomed to look upon all such rocks as obscure sedimentary masses, in and below which no succession of "strata as identified by their fossils" could be detected. The result of research, however, has been the elimination of several well-defined formations, all of which, in Germany, even including the lower carboniferous strata, were formerly merged in the unmeaning term "grauwacke."

Desirous of throwing light on this dark subject, I consulted my

* See those classical works, the first Geological Map of England, by W. Smith (1815), the subsequent map of Mr. Greenough (1819), and the Geology of England and Wales, by the Rev. W. D. Conybeare and W. Phillips (1822).

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valued friend and instructor, the late Dr. Buckland, as to the region most likely to afford evidences of order, and by his advice I first explored, in 1831, the banks of the Wye between Hay and Builth. Discovering in that year a considerable tract in Hereford, Radnor, and Shropshire, wherein large masses of grey-coloured strata rise out from beneath the Old Red Sandstone, and contain fossils differing from any which were known in the superior deposits, I then began to classify these rocks. After four years of consecutive labour, during which I received much valuable assistance from the Rev. T. Lewis, of Aymestry*, and Dr. Lloyd, of Ludlow, and exhibiting each year fossil evidences before the Geological Society to prove the independence and succession of the strata, I assigned to them (1835) the name "Silurian," deriving it from the portion of England and Wales in which the successive formations are clearly displayed, and wherein an ancient British people, the Silures, under their king Caradoc (Caractacus), had opposed a long and valorous resistance to the Romans. Having first, in the year 1833, separated these deposits† into four formations, and shown that each is characterized by peculiar organic remains, I next divided them (1834, 1835) into a lower and an upper group, an arrangement which I hoped would be found applicable to wide regions of the earth. After seven years of labour in the field and closet, the proofs of the truth of those views were more fully published in the large work entitled the 'Silurian System' (1838–9). As the quarto work is not in general circulation, let me put the reader in possession of some of the leading views it contains, by quoting the following passages, in which, having previously described the overlying deposits, the lowest of which is the Old Red Sandstone (since termed Devonian), I thus usher in the new classification:—

"We have at length reached [downwards to] those older deposits, which, not having been separated into formations by previous writers, I am compelled to describe under new terms.

* See Preface.

† For the first tabular view of these four formations, the lower one resting on the then so-called "unfossiliferous greywacke" of the Longmynd, see Proceedings Geol. Soc. Lond. vol. ii. p. 11, Jan. 1834. The chief characteristic fossil species were even then enumerated, and specimens placed in the Museum of the Geological Society, and hence the classification which is now sustained is essentially twenty-four years old. It had even been previously stated by me (in 1833) that the lowest *fossil*-bearing formation then known to me, or the "black trilobite schists and flags of Llandeilo, probably exceeded in thickness any of the superior groups."—Proc. Geol. Soc. vol. i. p. 476.

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"Acting upon the principle which guided William Smith in subdividing the oolitic system of our island, I have named these rocks from places in England and Wales where their succession and age are best proved by order of superposition and imbedded organic remains, and have termed them in descending order, the 'Ludlow,' 'Wenlock,' 'Caradoc,' and 'Llandeilo' formations. The same principle has led me to use the general term of 'Silurian System' for the group, to mark thereby the territory in which the best types and the clearest relations are exhibited.

"Like every other mass of strata entitled to the name of System, the Silurian, though clearly recognizable as a whole over extensive tracts, cannot always be subdivided into those formations which are displayed in the regions where I shall first describe it, and where its types are fully developed. Thus, for example, where the subordinate limestones thin out and disappear, the Ludlow deposit can seldom be clearly separated from that of Wenlock. In such cases both these formations are included in the term of 'Upper Silurian Rocks,' and, under similar circumstances, the Caradoc sandstones and Llandeilo flags in that of 'Lower Silurian Rocks.'

"Simple as this classification may now appear, those versed in practical geology can well understand what must have been the amount of examination employed in its perfect establishment. To comprehend the extent of the break in the history of the older strata which has been filled up by the study and classification of these rocks, the student has only to refer to the tabular view I have prepared, and compare it with other tables framed upon an antecedent state of geological knowledge. He will then perceive, that what is here presented to him as a well-ordered succession of great thickness (each subdivision of rocks being characterized by a corresponding suite of organic remains*), was formerly considered one assemblage, without definite sequence, and included under the unmeaning names of 'greywacke' or 'transition limestone.' I have already explained that the latter term has been as liberally bestowed (chiefly, however, by foreigners) upon the carboniferous limestone, from which the Silurian rocks are separated by that enormous

* These organic remains were laid before the Geological Society, and named, in each succeeding Session from 1831 to 1838, when the large work, the 'Silurian System,' was completed.

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accumulation, the Old Red Sandstone; whilst the organic remains of both these systems are entirely dissimilar from those of the carboniferous era..... Let us now proceed to consider these Silurian deposits in the natural order in which they appear in the south-west of Salop and adjacent parts of Herefordshire."

During my early researches (1833), it was shown that the lowest of these fossil-bearing strata then known to me, including the Llandeilo Flags, and their natural base the Stiper Stones, which latter were even then classed as Silurian, reposed, in the west of Shropshire, on a very thick accumulation of still older sediment, constituting the Longmynd mountain; and the strata of the latter, not then offering a vestige of former life, were at first termed 'unfossiliferous greywacke' *.

As in examining all the strata of England and Wales from south-east to north-west it had been found that there was a regular succession from younger to older rocks, so at the time when I propounded the Silurian classification (1835) it was the belief of all geologists † who had examined the country, that the slaty rocks of North Wales rose up from beneath my Silurian types of Shropshire and of the counties of Montgomery, Hereford, and Radnor. In this belief I coincided, without surveying the north-western tracts of Wales. Hence another term, or that of "Cambrian," which Professor Sedgwick proposed, and which, applied to the Longmynd of Shropshire, was in the year 1836, or a year after the introduction of the name "Silurian," also applied to rocks of North Wales. These rocks were supposed to be of older date, before their true relations, physical and zoological, to the recognized Silurian strata of Shropshire had been ascertained. The assumed inferior position of the slaty rocks of North Wales

* The Stiper Stones were classed by me in 1833 and 1834 as the base of the overlying series, which was termed Silurian as early as 1835. See Phil. Mag. vol. vii. p. 46, with a diagram showing such Silurian rocks reposing on 'unfossiliferous greywacke.' The Government Geological Surveyors have designated as Cambrian only, those rocks of Wales which, like my original type the Longmynd, underlie all the strata with Silurian fossils.

† See all the early geological maps, and even the last edition of the Map of Greenough (1839). In 1838 also, Professor John Phillips still held this belief as well as myself and others, and gave in the Penny Cyclopædia (art. GEOLOGY) a section across Britain, in which the Snowdon and North Welsh rocks are placed below the Caradoc and Llandeilo formations. The reader is further referred to the Preface.

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being considered a fixed point, it was naturally thought that such formations, the fossils of which were then undescribed, would be found to contain a set of organic remains differing as a whole from those of the classified and published Silurian system. With other geologists, therefore, I waited for the production of the fossils which might typify such supposed older sediments; for in obtaining the knowledge I had then acquired, by working down from upper strata whose contents were known, to lower and previously unknown rocks, I had invariably found that the inferior masses were characterized by distinct organisms. This principle, which had been first established in the tertiary and secondary deposits, was thus proved to be universally applicable, by the occurrence of similar distinctions in the Carboniferous, Old Red, and Silurian rocks.

It was, however, in vain that we looked to the production of a peculiar type of life from the North Welsh slaty rocks. Professor Sedgwick's collections derived from that region had long remained packed up and unexamined; but as soon as he called paleontologists to their inspection, Silurian fossils, already named in my works, were alone found in them, and the reason has since become manifest. The labours of many competent observers during the last twenty years have proved that these slaty rocks are not inferior in position, as they were once supposed to be by many geologists, to the Lower Silurian strata of Shropshire and the adjacent parts of Montgomeryshire, *but are mere extensions of the same*; and hence the looked-for geological and zoological distinctions could never have been realized. In the following chapters it will be shown how Sharpe, De la Beche, Ramsay, E. Forbes, and Salter, with several other explorers, have demonstrated, that the fossil-bearing rocks of North Wales are, both in their order and contents, the absolute equivalents of the chief mass of the strata long previously described and named by me "Lower Silurian" in Shropshire and Montgomeryshire. The above-named authors therefore applied and used the Silurian nomenclature in all their works relating to North Wales*, including in the group the Stiper Stones, in which, though in my early researches I found no fossils, Linguleæ have been since detected.

* See also Phillips, on the Malvern and Abberley Hills; Memoirs Geol. Surv. vol. ii. pt. 1. 1848.

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But although in 1838, when my large work was really completed*, I still held, in common with my associates, the erroneous idea of the infra-Silurian position of the slaty rocks of North Wales, I soon saw reason to abandon that view, and to adopt the opinion which I have maintained for the last eighteen years. I ascertained, in short, that in Bohemia, Scandinavia, and Russia, the chief inferior zone of primeval life was essentially the Lower Silurian of Britain. Indeed I made a transverse section in 1842, accompanied by my coadjutor Keyserling, north-westward from Shropshire, and was convinced that all the undulating fossiliferous rocks of North Wales were extensions of Silurian types. During those years the Government Geological Surveyors had arrived at similar results through their own labours, both in North and South Wales. In the latter country, Professor Ramsay first discovered (1842) that to the north and west of my typical position of Llandeilo, true Silurian rocks, characterized by their fossils, folded over, and occupied a wide region, which, without examination, I had erroneously mapped as of Cambrian or older date (simply because it lay to the north-west). Thenceforward Sir H. De la Beche and the Surveyors naturally coloured as Silurian all such hitherto undefined tracts. (See Map, and Section, p. 79.)

My view of the continental equivalents of the Silurian rocks of Britain, which I worked out in the same years, having been published in the year 1842†, was adopted generally in Europe and America; the independent researches of numerous foreign geologists leading them to the same conclusion.

In extending my own researches to various distant lands, I had found that as the base of all rocks containing well-defined Silurian fossils, in Bohemia, Scandinavia, and Russia, was clearly defined, and as the same fact was announced from North America, it was no longer difficult to describe the whole organic series from the first traces of life, and thus to record the succession of animals from their earliest distinguishable types. In a word, as chroniclers of lost races, de Verneuil, von Keyserling and myself were enabled, in

* Although 1839 is on the title-page, extracts from printed copies of the work were quoted by authors in 1838 (see Lyell's 'Elements of Geology' of that year).

† Discourse of the President of the Geological Society of London, 1842; Proceedings Geol. Soc. Lond. vol iii. p. 640 &c.

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1845, to register, in our 'Russia and the Ural Mountains,' the forms of ancient creatures apparently from their dawn. To the first chapters of that work, as explanatory of views which are here reiterated, the reader is referred. Then it was that positive proofs, derived from a vast field of observation, enabled us to commence the geological history of a region occupying half the area of Europe, with an account of the entombment of the earliest animals recognizable in the crust of the globe; and also to indicate the successive conditions which prevailed upon the surface, in a long series of ages, and during the many changes of outline which preceded the present state of the planet. Looking to all the records of former life, as exhibited in the strata, it was then demonstrated, from phenomena in one great empire alone (as had to a great extent been shown in Britain), that during the formation of the sediments which compose the crust of the earth, the animal kingdom had been at least three times entirely renovated; the secondary and tertiary periods having each been as clearly characterized by a distinct fauna as the primeval. In the work on Russia, the Ural Mountains, and Scandinavia, the sequence was thus followed out, from the most ancient fossil-bearing strata to the latest stages in the geological series.

The leading object, therefore, of this work is, I repeat, to bring out the 'Silurian System,' not as a mere abridgement of its original form; but such as it became in subsequent years, when it obtained the highest distinction which the Royal Society bestows *, and what it has since proved to be, with the additions made to it by numerous geologists at home and in foreign countries, as well as by myself.

In the present volume attention is chiefly restricted to what has proved to be the protozoic, or first great era of life. The plan, therefore, pursued will be, so far, similar to that which was adopted in the earlier chapters of the work on Russia; and these leaves of geological history will be written from the first traces we have obtained of organic remains,—a plan which, for want of knowledge, was impracticable in Britain when the 'Silurian System' was issued in 1838.

Since the first edition of this work was published in 1854, and even after many pages in the following chapters were printed, an

* The Copley Medal (1849).

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important addition has been made to our acquaintance with the relations of the lowest or fundamental unfossiliferous rocks of the British Isles, to which it is necessary at once to allude. The oldest gneiss of Scotland, particularly on the west coast of Sutherland and Ross, is seen to be unconformably surmounted by mountain masses of conglomerate and sandstone, which, though formerly mistaken by all geologists for "Old Red Sandstone," are now demonstrated to be of Cambrian age, since they are transgressively overlaid by strata of quartz-rock and crystalline limestone, in which, through the labours of Mr. C. Peach, Silurian organic remains, belonging to what may be called the lowest part of the Llandeilo formation, have been found.

In the lithograph given in the Frontispiece an attempt has been made, to represent, by colour and some indications of the stratification*, the succession of these rocks as seen in looking westward from Inchnadamff on Loch Assynt in Sutherland. The reader may be informed that the low distant hills form the sea-coast, and consist of that fundamental gneiss (*a*) which is older than any rock in England and Wales; that the lofty mountain of Queenaig, composed of horizontal chocolate-coloured sandstone and conglomerate (*b*), is of the same age as the Cambrian rocks of the Longmynd in Shropshire, and Harlech in Wales, that lie beneath the whole of the Silurian strata of Wales and England; whilst the overlying sloping masses which descend into the foreground are quartz-rocks or altered sandstones (c^1 and c^3) with included crystalline limestones (c^2), which (when they range into Durness) contain about twenty species of Lower Silurian fossils.

These striking features are further illustrated in the sequel (pp. 179, 195, 216, and Appendix B.), and the reader, having now had his notice directed to them, will proceed in the second chapter to the consideration of the oldest known rocks of the original Silurian region of England and Wales.

After a short sketch of the earliest zone of sediments of that region, or the Cambrian of the Maps of the Geological Survey made under Sir H. De la Beche, in which feeble traces only of former life

* In this sketch, more strength is given to the relative stratification of the masses as known to the geological observer, than can be observed in the outlines of nature; and the young lady who made the sketch must pardon the liberty which has been taken with her pictorial delineation.

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have been detected, full descriptions will be given of the Lower and Upper Silurian rocks. To the first of these many pages will be devoted, whilst other chapters will treat exclusively either of the strata which unite the two groups (and which are now termed Llandovery rocks), or of the upper members of this great natural series or system. Whilst so separated for purposes of classification, it will, however, be clearly shown, that, through their organic remains, these deposits comprehend but *one great system of life*. Condensed accounts will then follow of the overlying or younger paleozoic groups termed Devonian, Carboniferous, and Permian; one only of these (the Carboniferous) constituting what may be called a system. In fact, the Devonian is simply an intermediate zone between the Silurian and Carboniferous systems, while to the last is closely linked on the Permian deposit.

The Devonian rocks were in previous years known only as the Old Red Sandstone, a name which has become classical through the writings of the lamented Hugh Miller. These were termed Devonian, because the strata of that age in Devonshire, lithologically very unlike the Old Red Sandstone of Scotland, Hereford, and the South Welsh counties, contain a much more copious and rich fossil fauna, and were shown to occupy the same intermediate position as the Old Red Sandstone, between the Silurian and Carboniferous rocks. At that time, however, none of the fossil fishes of the Scottish or English Old Red had been found in the slates, schists, sandstones, or limestones of Devonshire, or the Rhine, and objections might therefore have been raised to the term "Devonian" as applied to the Old Red deposits. But the discovery made in Russia *, of the same species of Scottish ichthyolites being there associated with forms of mollusca found in Devonshire,—similar tests being afterwards extended to Belgium and the Rhenish provinces,—firmly established the truth of the comparison. It was also shown by myself that the uppermost Silurian rocks of Norway (Christiania) are surmounted by copious masses of Old Red Sandstone †.

The Carboniferous rocks, so largely and fully developed in the British Isles, have been well investigated by many writers, particularly by Professor Phillips, and they have been found to extend,

* See Russia in Europe and the Ural Mountains, vol. i. p. 64.

† Russia in Europe and the Ural Mountains, vol. i. p. 13; and Quart. Journ. Geol. Soc. vol. i. p. 469, and vol. viii. p. 182.

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like the Silurian and Devonian, over immense regions in all quarters of the globe.

The great primeval or paleozoic series is now known to terminate upwards, in Europe, with certain deposits, for which, in the year 1841, I suggested the name of "Permian." In the earlier days of geological science in England, this group was classed with the New Red Sandstone, of which it was supposed to form the base; but extended researches have shown, from the character of its imbedded remains, that it is closely united with the Carboniferous deposit below it, and is entirely distinct from the Trias, or New Red Sandstone, which, overlying it, forms the base of all the secondary rocks. The chief calcareous member of this Permian group was termed in Germany the "Zechstein," in England the "Magnesian Limestone;" but, as magnesian limestones have been produced at many different periods, and as the German "Zechstein" is a part only of a group, the other members of which are known as "Kupfer-Schiefer" (copper-slate), "Roth-todt-liegendes" (the "Lower New Red" of English geologists), &c., it was manifest that a single name for the whole was much needed. After showing how these variously named strata constituted *one natural group* in Germany as in other countries, I proposed to my fellow-labourers, de Verneuil and von Keyserling, that the vast Russian territory of Perm should furnish the required name*. The general adoption of the term "Permian," both at home and abroad, is, indeed, the best proof of its usefulness.

In the opening chapter on the geology of Russia, a general view of this paleozoic classification was given, as applied to Germany, France, Belgium, and North America; and in all of these countries, as well as in Russia, it was shown, that a similar ascending order prevailed, from a base-line of recognizable Silurian life, through Devonian and Carboniferous deposits. In the thirteen years which have elapsed since the issue of that work, considerable additions have been made to our knowledge, and all of them sustain the truth of the generalization. We then scarcely knew of the existence of true Silurian deposits in Germany, nearly all the greywacke of the Rhenish provinces and the Harz having been assigned to the Devonian series; but since the opening out of the rich Silurian

* See my letter to Dr. Fischer, Moscow, Oct. 1841, printed in Leonhard's N. Jahrb., and in Phil. Mag. vol. xix. p. 419.

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basin of Bohemia, which, in the skilful hands of M. Barrande, has become the paleozoic centre of the continent, Thuringia and Saxony have been also found to contain Silurian rocks.

In Spain, several mountain-chains have been shown by M. de Verneuil and M. Casiano de Prado to consist of Silurian, followed by Devonian and Carboniferous rocks; whilst, in Portugal, Mr. D. Sharpe has described the first and last of these groups. Again, Sardinia, under the scrutiny of General A. della Marmora, has exhibited its Silurian and superjacent coal deposits. As Devonian and Carboniferous strata overlie older rocks in North and possibly in South Africa*, there are indeed already fair grounds for believing that an order similar to that of Europe pervades the ancient encircling mountains of that vast continent.

In Siberia, the chief mineral features of which are described by Humboldt and Rose, my colleagues and myself have explained how the Silurian rocks of the Ural chain are succeeded by younger paleozoic deposits; and Pierre de Tchihatcheff has indicated a great extension of similar formations over large tracts of Southern Siberia and in the Altai Mountains; whilst to the north-east, Adolf Erman has traced such rocks even to the Sea of Ochotsk.

In the giant Himalaya, where, a few years since, no systematic labours had been devoted to the older strata, we now know that Silurian rocks, covered by secondary or mesozoic deposits, exist in those the highest mountains of the world; and that the Upper Punjaub of Hindostan contains a limestone charged with well-known carboniferous fossils, reposing, as in England, upon a red sandstone†. It is also certain that the mountain-chains of China are composed, to a great extent, of these older rocks; for M. C. Skatschkof, Director of the Russian Observatory at Pekin, who is preparing an

* For North Africa, see Coquand, Bull. de la Soc. Géol. de France, 2 série, vol. iv. p. 1188. Some of the fossils collected by the lamented traveller Overweg, in his journey southwards, are also Devonian. For South Africa, the reader may consult a Memoir by Mr. Bain, published in the Trans. Geol. Soc. Lond. vol. vii. 1856. According to my distinguished friend Dr. Livingstone, the only European who has traversed and retraversed South Africa in such latitudes, coming out in the west at St. Paul di Laonda (lat. 10°), there are strong beds of coal and iron-stone on the affluents of the Zambesi, and to the north-west of the Portuguese settlement of Tete.

† The Himalayan data are given by Capt. R. Strachey; those of the Upper Punjaub, by Dr. A. Fleming (Quart. Journ. Geol. Soc. vol. vii. p. 292, and vol. ix. p. 189) and by Mr. Theobald (Journ. Bengal Asiatic Society, 1854, p. 651 &c.).

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account of the rich coal-fields (partially described by his countryman Kovanko) near that city, has in a recent visit to London recognized, in the Jermyn Street Museum, certain Silurian Graptolites and Orthoceratites, Devonian Spirifers, and Carboniferous Producti, as being all forms which he had seen in the rocks around the Chinese metropolis. A large collection of these fossils will be soon brought by M. Vasilefsky to St. Petersburg. Again, Devonian fossils of the very same species as those of England and the Continent have recently been given to me by Mr. W. Lockhart*, some from the interior province of Szechuan, and others from Kwangsi. Other fossils, identified by de Koninck as Devonian forms, were brought by M. Itier from the Yuennan province, one hundred leagues north of Canton †.

In Australia, where, a very short time since, reference could be made only to rocks of the Carboniferous and Devonian age‡, we hear of many Silurian fossils both in New South Wales and in Victoria§ like those of the British Isles‖. In Victoria, indeed, upwards of sixty species of Lower Silurian fossils have already been recognized in those slaty rocks which bear the chief auriferous quartz veins.

In South America, the lofty Cordilleras and plateaux, whose mineral characters had been so admirably described by Humboldt, were shown by Alcide d'Orbigny to consist in great part of such ancient sediments. Still more clearly has North America been found to contain a vast succession of these paleozoic rocks, and especially of their lower members. Numerous geologists of the United States have demonstrated, that their ancient strata followed

* See Proceedings of Roy. Geographical Soc., President's Address, 1858, vol. ii. p. 306.

† See a description of the Chinese coal-field near Pekin, by Kovanko, Ann. des Mines de Russie, An. 1838, p. 191. No geologist can peruse Mr. Fortune's lively description of the Bohea Mountains without supposing that a fine primeval succession may there be found. For the Chinese Devonian fossils, see Davidson, Quart. Journ. Geol. Soc. vol. ix. p. 353; and de Koninck, Bull. Acad. Roy. Sc. Belg. vol. xiii. pt. 2. p. 415.

‡ See Strzelecki's 'Australia,' Foss. Fauna, Morris; M'Coy, Ann. Nat. Hist. 1847; Lonsdale, Descrip. of the Corals, MSS., sent to me whilst this edition was in preparation.

§ The numerous fossils found in the Victoria Colony are considered by Mr. Selwyn, the able Government Surveyor, to be either of Lower Silurian age, or belonging to the zone which I now term Llandovery Rocks (Edinb. New Phil. Journ. n. s. i. p. 171; and Quart. Journ. Geol. Soc. vol. xiv. p. 533).

‖ Memoir by the Rev. W. B. Clarke, Quart. Journ. Geol. Soc. Lond. vol. viii.; see also his collections sent to England, and those at the public Museum of Sydney.

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the same order on a very grand and, in the western region, on an unbroken scale; doubtless due to their having been exempted in those tracts from the intrusion of igneous rocks. Spread out in enormous sheets over the southern districts of Upper Canada, the strata paralleled with the Lower Silurian by Logan and the American geologists* are there based on unfossiliferous slates, limestones, and sandstones, termed "Huronian," which, in their turn, repose on the crystalline rocks named "Laurentian;" thus showing that America offers the same primeval succession as Britain. (See *ante*, p. 12, and Frontispiece.)

The voyages of our bold Arctic navigators and travellers in search of the lamented Franklin have led to the discovery of many well-known Upper Silurian, Devonian, and Carboniferous fossils in limestones amid the polar ices; whilst adjacent to the southern end of America, fossil remains, certainly of Lower Devonian date, have been collected by Darwin in the Falkland Islands.

In few of those regions, however, with the exception of North America (certainly not in the British Isles, where the strata are in many parts much obscured by igneous outbursts), is the order so undisturbed as in Scandinavia and European Russia. There, the successive primeval deposits extend over a large portion of the earth in regular sequence, and in an unaltered state. Hence, though to the unskilled eye Russia presents only monotonous undulations, chiefly covered by mud, sand, and erratic blocks, its framework exhibits a clear ascending series. The older sedimentary strata, deviating but slightly from horizontality, are overlaid by widely diffused masses of those Permian rocks which constitute the true termination of the long paleozoic period.

The following pages, as before said, will be chiefly devoted to those stages of the primeval formations which are truly fossiliferous—the Silurian. They will be illustrated by woodcuts representing the most important organic remains, and certain pictorial scenes, as well as sections, chiefly taken from my former works. Faithful transfers from the original plates of the 'Silurian System' will

* See particularly the works of James Hall and Dale Owen; the Reports and maps of Logan, the chief geologist of Canada; the maps of Lyell, as compiled from the works of the United States' geologists, and the recent general map of North America by Marcou. See also the table by Ramsay, p. 472.

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also be given, in a re-arranged form, with the modern nomenclature of the fossils, and with the addition, on this occasion, of the Corals, so admirably described by my valued friend and coadjutor Mr. W. Lonsdale*.

Were the next three paleozoic groups to be equally elucidated, this work would be expanded far beyond the limits to which I must restrict it. The younger paleozoic, or the Devonian, Carboniferous, and Permian, deposits, will therefore be only so far dwelt upon as may be sufficient to give the student a general view, and stimulate him to acquire a fuller acquaintance with them by consulting the various works wherein they are circumstantially described. But even the sketch of them in this volume will, it is hoped, suffice to show, that while the contiguous strata of two natural groups are intimately linked together by containing species which are common to both, the principal fossils of each are certainly peculiar.

Although few of the mineral changes of the strata can be alluded to, an endeavour will be made, in the nineteenth chapter, to show that gold, however it may now be spread over the surface, has been introduced in abundance into the older deposits only, and chiefly into those of Lower Silurian date, or has accompanied certain associated eruptive rocks.

Lastly, it is to be observed, that as the true succession of the chief masses of the earlier fossiliferous strata was first detected in England and Wales, so the geological descriptions in this volume will be principally derived from our typical insular examples. At the same time, a general comparison will be instituted with the contemporaneous rocks in different quarters of the globe.

The importance of having, through patient surveys, mastered the obscurities which clouded the history of the earlier periods of organic life, will thus, it is hoped, be rendered obvious, in showing that we have now obtained as correct an insight into the primeval fossil-bearing formations as we had previously acquired of the nature and history of the younger deposits.

* The large plates of Corals (Pl. 38 to 41), which are now reproduced from the original 'Silurian System,' did not appear in the first edition of this work, it being erroneously supposed that the lithographic stones had been destroyed. I much regret (this chapter being the last printed) that no reference could be made to them when the body of the work passed through the press. (See Preface.)

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CHAPTER II.

BASE OF THE SILURIAN ROCKS, AND EARLIEST SIGNS OF FORMER LIFE.

OUTLINES, STRUCTURE, AND ORDER OF THE OLDER ROCKS.—EARLIEST CRYSTALLINE ROCKS.—THE LOWEST KNOWN SEDIMENTARY OR CAMBRIAN DEPOSITS AFFORD VERY RARE TRACES ONLY OF FORMER LIFE.—ORDER OF CONFORMABLE SUCCESSION UPWARD TO THE ZONE IN WHICH WELL-CHARACTERIZED FOSSIL REMAINS OCCUR.—SLATY CLEAVAGE.—METAMORPHIC ROCKS.

THE most ancient rocks in which fossil animals have been detected vary much in structure and outline in different regions. Wherever such masses have remained in a state of comparative quiescence, from the period when they were raised up from beneath a primeval ocean, and have since been modified to a slight extent only, they are necessarily unlike those strata which, though formed at the same period and even composed of similar materials, have been penetrated by igneous matter, or subjected to alteration through the action of mechanical pressure, heat, and other agencies.

In Russia *, where some of the older deposits have been but partially hardened since they were accumulated at the bottom of the sea, and have been elevated into merely low plateaux that have undergone no great change or disruption, they have scarcely a resemblance to any rocks of the same age in other countries. When, however, we follow these soft primeval strata to the Ural chain, a region abounding in eruptive rocks, we find that the beds, which on the west consist of mud and sand, have there been converted into crystalline schists, limestone in the state of marble, and auriferous quartzites. In Britain, no more striking examples of these changes of physical conditions can be seen than in the territory whose geological structure is explained in this work and the accompanying map. Throughout that portion of the region (Shropshire and Herefordshire) which afforded the types for the Silurian classification, the strata consist of shale, sandstone, and limestone, which, though much more consolidated than their equivalents in European Russia,

* Russia and the Ural Mountains, by Murchison, de Verneuil, and von Keyserling, vol. i. p. 26*.

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have been wholly unaffected by that influence which has impressed upon the very same beds, when followed into Wales, a true slaty cleavage. Or, if we trace those slates of North Wales across the Menai Straits, we find that they have undergone another change, and have become crystalline and metamorphosed into a different condition. So again in the United States and British North America, strata formed during the earlier periods are, throughout extensive regions, composed of ordinary sandstone, slate, and limestone; but when pursued eastwards across the undulations of the Appalachian chain and to the eruptive rocks of the sea-board, or westwards to the Rocky Mountains, these sediments are found to have been converted into masses more or less crystalline.

This is the change which geologists call metamorphism, a transmutation which is generally believed to have been produced by great internal heat acting upon deposits subjected to the pressure of a former ocean.

It will presently be shown, that the comparatively low hills of Shropshire and Herefordshire, and the adjacent tracts of Wales, present to the student, in an intelligible manner, a succession of unaltered strata, which has been with much difficulty deciphered amidst the hard, rugged, metamorphic, and crystalline formations of the same age in North Wales;—even when most of the obscurities have been removed by the labours of the eminent persons who, from Professor Sedgwick downwards, have toiled in the arduous task of bringing the geology of that region into order *.

In Russia, the Silurian rocks form either wide level plains or low plateaux; whilst in other countries, where they have been heaved up into mountains, they have a rounded outline, especially where they consist of schists, originally composed of mud, the fine grains of which have given rise to equable atmospheric attrition. When, on the contrary, the shale and schist have been changed into hard slates, the sandstone into quartz rock, or the earthy limestone into crystalline marble, and particularly if the beds be highly inclined and penetrated by igneous rocks, then sharp peaks or abrupt cliffs and gorges are dominant. Thus it is, that the same ancient strata of different regions put on so many different external forms. In

* For the works published on this subject in Britain, and the order in which they appeared, see Appendix A.

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South Britain they are, necessarily, most varied in districts which, like those of North Wales and Cumberland, have had their outlines diversified by the intrusion of igneous rocks.

Observation has now taught us of what materials the fundamental rocks of different countries consist. In Scandinavia, for example, as in parts of North America, the masses beneath all those formations in which there are the slightest vestiges of Silurian life are primary rocks, including granitic gneiss, mica-schist, as well as metalliferous schists and quartzose crystalline masses. In Bohemia, however, as in Great Britain and portions of North America*, the lowest zone containing distinct fossil remains is underlaid by very thick basements of earlier sedimentary accumulations, whether sandstone, schist, or slate, which, though occasionally not more crystalline than the fossiliferous beds above them, have as yet afforded the rarest indications only of former beings in Britain, and none in other countries.

This is the important fact to which attention is first directed; for in such instances the geologist appeals to strata which have undergone no alteration. In this enormous pile or series of early subaqueous sediment, composed of mud, sand, or pebbles, the successive bottoms or shores of a former sea, all of which had been derived from pre-existing rocks, he has been unable, after many years of research, to detect more than the feeblest traces of former creatures. But lying upon them, and therefore evolved after them, other strata succeed, in which a certain number of clear relics of a primeval ocean are discernible; whilst these again are everywhere succeeded by deposits containing many organic remains. In this way, evidences have been fairly obtained to show, that the sediments which underlie the strata containing the oldest clearly manifested

* In North America this formation may as yet be truly termed azoic; for along the western portion of Lake Superior, and in the country extending southwards into the State of Michigan, rocks of this class rise from beneath the Potsdam sandstone, or lowest formation in which Silurian fossils are known. Judging from the publications of the American authors Foster and Whitney on the azoic rocks of Lake Superior, of King on the State of Missouri, of Logan on the British frontier, and of Engelmann on Texas, and placing them in relation to the works of James Hall and Dale Owen, it would appear that in those regions there exists a vast formation of strata, in parts metamorphic, of siliceous sandstones and chloritic and quartzose schists, characterized by the absence of organic remains, and the presence of a great abundance of iron ore. This is the Huronian or Cambrian System of Sir William Logan, chief geologist of Canada.

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fossil remains constitute, in all countries which have been examined, the natural base of the deposits termed Silurian.

The hypothesis that all the earliest sediments have been so altered as to have obliterated the traces of any relics of former life which may have been entombed in them, is therefore opposed by examples of enormously thick and often finely levigated deposits beneath the lowest fossiliferous rocks, and in which, if many animal remains had ever existed, more traces of them would be detected.

Very few words need here be said of those crystalline masses which in numerous regions have been the nuclei out of whose materials the oldest recognizable sediments have been composed. Passing over the consideration of the most ancient granites, porphyries, and other igneous rocks, there are doubtless also strata, now in a crystalline state, which either lie under or have been raised from beneath all deposits of mechanical and subaqueous origin.

Such rocks may have been formed at a period when the heat of the crust of the earth was antagonistic to the existence of living beings. At all events, they often constitute the axes or backbones of continents, and upon the sides of these the oldest sedimentary formations have been deposited. There are, however, other crystalline strata, that have, until very recently, been also placed in this category, but in which traces of organic remains have been found. To these allusion may be made in the sequel, when we shall have to indicate the metamorphism of formations of younger date. The present work is chiefly intended as a sketch of the successive accumulation of those sedimentary strata in which the remains of the earliest known animals are entombed; the physical conditions which accompanied the formation of such deposits being duly noted.

Now, in some regions where the oldest of these deposits have been exempted from such change or metamorphism, we observe, I repeat, that the lowest portions, thus accumulated, are almost void of traces of life. Proceeding in our researches, we find that the most ancient grits and schists recognized by geologists, deposited by water from the waste of previous rocks, are succeeded regularly, and without disorder, by other strata, scarcely at all differing from the former in composition, in which, at various points of the surface of the globe, and at the same level or horizon, we obtain much more distinct proofs of animal relics. Once introduced to

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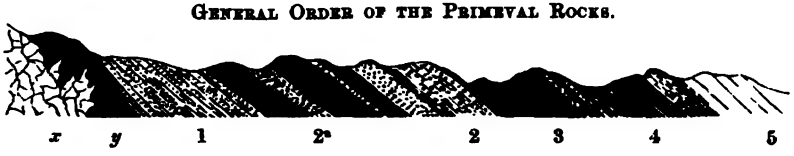
these primordial creatures, the inquirer into the operations of nature meets thenceforward with a never-failing storehouse of organic remains in all the formations which were afterwards successively accumulated. The accompanying diagram explains at a glance this generalization, as established by an appeal to the structure of every well-explored country whose rocks exhibit the first terms in this long series.

GENERAL ORDER OF THE PRIMEVAL ROCKS.



Gneiss, &c. *y*; granite, *x*.

The strata marked "1" are the older deposits which have been formed out of the pre-existing rocks of gneiss, ancient slates, &c. (*y*), or granite (*x*). In No. 1 (the Cambrian of the British Geological Surveyors), the feeblest indications only of former life have been detected; whilst the overlying accumulations, 2ª, 2, 3, 4, 5, stand for the principal formations into which the Silurian or earliest primeval system of clearly defined fossil animals is divided.

In the mean time, let us recollect, that in Bohemia, as well as in North America, there are crystalline rocks, which, from their underlying position, as given in this little diagram (*y*), are known to be of higher antiquity than our British fundamental sedimentary rock, or No. 1 of the section.

But although there are countries, both in Europe and America, containing primary crystalline rocks, which, like the masses *x*, *y* of the preceding diagram, are seen to be of higher antiquity than the unaltered sediments overlying them, yet in no part of England and Wales have any rocks been proved to be of more remote age than the basement strata No. 1 of the above diagram.

Cambrian or Basement Rocks of the Silurian Region, and their equivalents in Wales. (See Map, fig. 1.)—Let us first review the older rocks in the ascending order above alluded to, and as they were first studied in the western tract of Shropshire, where the lowest strata containing clearly defined fossils are seen to repose upon a vast mass of still older deposits, in which the slightest traces only of former life have been but recently detected. It

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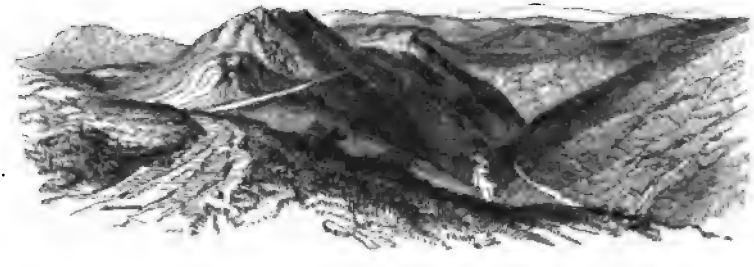
will afterwards be shown how the same succession prevails in the slaty regions of Wales, to which the Silurian classification has been subsequently applied.

The northern portion of the Silurian Region, or the south-western part of Shropshire, is marked by the rise of a group of hills which presents to the eye an outline and a vegetation different to those of the surrounding elevations. When inquired into by the geologist, this semi-mountainous mass is found to be composed of the most ancient recognizable sediments of the British Isles. Generally known under the name of the Longmynd, these round-backed hills, which suddenly flank the western side of the road from Ludlow to Shrewsbury, rise to heights varying from 1400 to 1600 feet above the sea. Ranging from N.N.E. to S.S.W., they stand boldly out from beneath the surrounding Silurian deposits, of which they form the mineral axis.

The annexed woodcut is merely given to convey some idea of their form when looking from one of the transverse openings on the



THE LONGMYND*.

eastern slope towards the valley of Church Stretton. The elevations perceived beyond these hills are, first the sharp ridge of Caradoc, then the Wenlock Edge; the Clee Hills appearing in the distance.

The lowest strata of the Longmynd, or those forming the base of their eastern escarpment, range along the western side of the

* This sketch, and several others relating to this tract, which were made use of in the publication of the 'Silurian System,' were drawn by that sound geologist, the late Mr. Thomas Webster, many years Secretary of the Geological Society. These drawings were prepared to illustrate a manuscript on the geology of Shropshire, intended for publication by my esteemed friend, the late Mr. Arthur Aikin, but which he had put aside for some years, when, perceiving that I had discovered an order of succession in this region, which had escaped him and his associate, he kindly placed his materials at my service.

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Stretton valley. They are thin, fragile, glossy schists or clay slate, with two or three minute layers of siliceous limestone, each scarcely exceeding an inch in thickness. These beds, partially interfered with by bosses of eruptive trap-rocks, dip to the W.N.W. and are overlaid by a vast and regular series of hard, purple or plum-coloured, greenish and grey schistose flagstones and siliceous grits. The whole of this series can be well observed in order of superposition along the banks of the small brook which descends by the Carding Mill to Church Stretton, and in other parallel transverse gullies. Quartz veins occur here and there; but on the whole these strata consist simply of sandstone rock, both schistose and gritty, and often finely laminated, in which the lines of deposit, and even the rippled surfaces of the beds, are distinctly visible; the mass being scarcely affected by any slaty cleavage.

The rocks of the Longmynd proper, being highly inclined to the W.N.W., are overlaid in that direction by other masses of very considerable dimensions, including purple sandstones, conglomerates, and grey schists, which range from Linley to Church Pulverbatch, the highest of them dipping conformably under the remarkable ridge of the Stiper Stones, with which, as originally defined, the Lower Silurian strata commence.

It is to the whole of this huge accumulation of schists, with sandstone, grits, and pebbly beds, lying between the valley of Stretton and the Stiper Stones, that the term of Unfossiliferous Grauwacke was first applied by me in 1833, and was long afterwards changed into that of Cambrian*. It is important here to remark, that the thickness of these rocks in Shropshire has been estimated, by the Government Surveyors, at not less than

* See Proceedings Geol. Soc. vol. i. p. 475. In this publication of the year 1833, after describing, in descending order, the Ludlow and Wenlock rocks as being underlaid by 'Shelly Sandstones' and 'Black Trilobite Flagstones' (the whole united in 1835 under the term Silurian), I thus spoke of the subjacent 'Red Conglomerate, Sandstone, and Slaty Schist,' forming the higher portion of the Longmynd:—"This is a vast deposit of several thousand feet in thickness, consisting of very coarse quartzose conglomerates, which alternate with some schistose beds and much purple-coloured sandstone (the Compound Sandstone of Townsend), the strata of which in Haughmond, Pulverbatch and Linley Hills, Shropshire, are highly inclined or vertical, in conformity with those of the preceding formation. No organic remains have been observed, by which, and by its very peculiar mineral structure, this formation is shown to be entirely distinct from the preceding (overlying) groups." See also Philosophical Magazine and Annals of Philosophy 1835, vol. xviii. p. 46; and Silurian System, p. 268, and pl. 32. figs. 1, 2, 3.

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26,000 feet, as exposed in their highly inclined edges; the beds dipping at the average inclination of about sixty degrees to the W.N.W.*

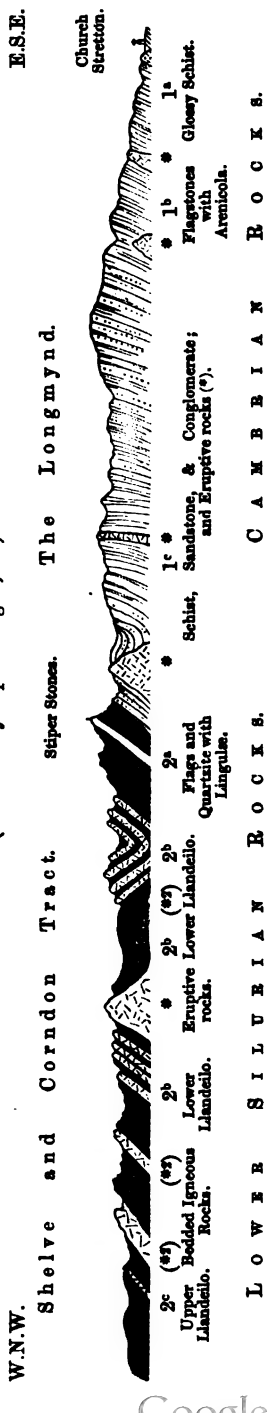
The opposite diagram, reduced from my original sections, representing the general relations of these Longmynd or Cambrian rocks to the strata which were first defined as the Lower Silurian types, will convey a clear idea to the reader of that order which every geologist may examine for himself, when he walks from the valley of Church Stretton across the Longmynd to the well-marked ridge of the Stiper Stones, and thence into that typical Lower Silurian tract of the Shelve and Corndon district, which will presently be illustrated.

In the 'Silurian System,' as well as in Memoirs published some years previously by the Geological Society, I described the Longmynd rocks in detail, and showed, that, besides the strata of obviously mechanical and subaqueous origin, there are associated with them eruptive rocks, whether greenstones or other trap rocks, which had been intruded, and had in part altered the deposits they penetrated. It was further stated, that

* According to the same authorities, the Cambrian rocks at Harlech in North Wales, which are equivalents, are not thicker than about 8000 feet.

SECTION FROM THE LONGMYND ON THE E.S.E. ACROSS THE STIPER STONES TO THE TRACT OF SHELVE AND CORNDON ON THE W.N.W.

(From Sil. Syst. pl. 32. fig. 1, &c.)



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some of the altered rocks contained copper veins, and that others had cavities lined with crystals of quartz, and occasionally with bitumen or mineral pitch*. The exudation of mineral pitch from rocks of the same age and character, both at Haughmond Hill to the north of Shrewsbury and at Pitchford, to the east of that town, was further pointed out, as well as the frequent recurrence of thin strings of copper ore.

The geologist will naturally attach much interest to the occurrence of occasional flakes of anthracite in, and to the flow of petroleum from, these very ancient strata. For if these substances were formed out of vegetable or animal matter, we can refer to seaweeds or minute worms only as the sources of them†.

Neither during the period extending from 1831 to 1835, during which I first explored them, nor in subsequent years, when searched by the surveyors and collectors of the Geological Survey, up to the time when the first edition of this volume was published (1854), had any traces of organic remains been discovered in these Longmynd Rocks, and hence, whilst their position and mineral characters were described, they were still spoken of as 'unfossiliferous,' or as 'having not yet afforded signs of any former beings‡.' Mr. Salter has been so fortunate, however, as to discover faint traces of animal life in these old sediments. In several courses of the hard, siliceous, purple and grey flagstones, low in the series, and overlaid by many thousands of feet of strata in which no fossils

* The manner in which certain cavities of these rocks are filled with bitumen and small patches of anthracite (Sil. Syst. pp. 260, 265 *et seq.*), and also the veins of copper ores which they contain near the junction of the intrusive rocks, are facts worthy of attention.

† The origin of the bitumen exuding from the interior of these very ancient deposits is necessarily most difficult of explanation. To satisfy his mind on this subject, the reader may consult with advantage a memoir by M. Abich, in the Acad. Sc. St. Pétersbourg, Bull. Phys. Math. tom. xiv. nos. 4 & 5, in which the author, insisting upon the intimate connexion between the gases proceeding from mud volcanos and other volcanic outbursts, dwells on the close geological affinity existing between all such operations, including hot springs, &c., and the different sorts of bitumen, asphalt, &c. M. Abich views petroleum (like that which issues from the rocks of Pitchford and Haughmond Hill: see diagram, Sil. Syst. p. 265) as a compound primitive body engendered in the interior of the globe, whence it rises like carbonic acid, of which the real origin is also unknown.

‡ That few animals existed during the formation of these rocks has received support from certain experiments of Dr. Daubeny, who has been unable to detect any phosphate of lime in them; though in the overlying Silurian formations, in which animal remains occur, there are abundant indications of that mineral.—See Quarterly Journal of the Chemical Society, vol. vii. p. 289.

Even in the slender calcareous laminæ recently discovered by Mr. Salter at Church Stretton, Dr. Percy has been unable to detect any appreciable amount of the phosphate.

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have been detected, he has discovered certain indications of the existence of animals at that period.

The impressions represented in fig. 1 are described as the surface-holes made by Annelides, which formed burrows in the sand, like the lob-worm of our coasts. The sand-worm which left these impressions is distinguished under the name of Arenicola didyma*. Together with the sinuous tracks or trails of such animals, the same author also finds in the minute markings upon the rippled surface

FOSSILS (1).

Fig. 1.

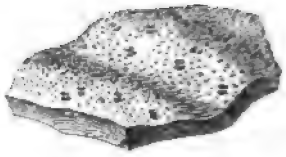

Fig. 1. Burrows of Annelides allied to Arenicola. (A. didyma, Salter.)

Fig. 2.

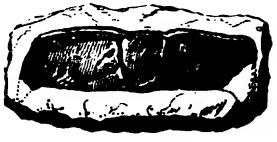

Fig. 2. Palæopyge Ramsayi, Salter.

of the strata, evidence of littoral or shore conditions,—an inference which is strengthened by the occurrence of the water-worn pebble beds, which are seen to prevail in the same series of strata as you ascend towards the summit of the Longmynd.

The fossil next represented (fig. 2) is supposed by Mr. Salter to be the caudal part, or *pygidium*, of a Trilobite, which he has named Palæopyge Ramsayi. He considered it to be probably allied to the crustacean Deikelocephalus described by Dale Owen, from some of the lowest beds of the 'Silurian series' of that author, in the newly explored region of Wisconsin, Iowa, and Minnesota (United States)†.

Desirous of ascertaining whether these faint signs of primordial life might not lead to better evidences of a clear and recognizable fauna, I requested Mr. Salter, accompanied by a zealous young collector‡, to re-examine those Longmynd strata in detail in which it appeared likely that a fossil could be detected. These researches have, it is true, brought to light several other highly curious confirmations of the minute tracks or impressions having been made by Annelides; but neither in the overlying strata of the

* Journ. Geol. Soc. Lond. vol. xii. p. 248.

† See the work by Dale Owen, entitled 'Report of a Geological Survey of Wisconsin, Iowa, and Minnesota.' Philadelphia, 1852. See also the Longmynd fossils described in the Quarterly Journal of the Geological Society, p. 246, 1856.

‡ Mr. John Rhind.

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Longmynd, nor in the prolongation of the same beds in which the so-called Palæopyge was found, has any additional evidence been procured of the existence of crustaceans. That uncertain form (fig. 2) stands therefore as yet alone, to sustain the belief that animals of so high an organization as Trilobites were extant when these ancient sediments were accumulated.

Let us here observe, that the fine aggregation and unaltered condition of these sediments have permitted the minutest impressions to be preserved. Thus, not only are the broad wave-marks distinct, but also those smaller ripples which may have been produced by wind, together with apparent rain-prints, as seen upon the muddy surface, and even cracks produced by the action of the sun on a half-dried surface. Again, as a further indication that these are littoral markings, and not the results of deep-sea currents, the minute holes left by the Annelides (fig. 1) are most conspicuous on the sheltered sides of the ripples in each slab.

Surely then, if animals of a higher organization had existed in this very ancient period, we should find their relics in this sediment so admirably adapted for their conservation, as seen in the markings of the little Arenicola, accompanied even by the traces of diurnal atmospheric action.

In North Wales, where the same Cambrian or Longmynd rocks occur, no fossils, except marine plants or fucoids, have been detected in them. In Ireland, however, where masses unquestionably of the same age prevail in the picturesque rocky tract to the S. and S.S.E. of Dublin, they contain two species of a peculiar zoophyte, which, having been detected by Professor Oldham * in the purplish hard schists of Bray Head, received the appropriate name of Oldhamia from Professor Edward Forbes.

The Oldhamia is a polype, or perhaps a coralline, of which two species have been collected, and one of them is here given. It occurs in the hard rocks forming Bray Head, and at Carrick MacReilly, Wicklow; but the species here figured is most abundant at the last-mentioned of these places.

The reader may look with reverence on this zoophyte as the oldest relic of its class yet discovered. It is well preserved, and reminds

* Then Local Director of the Geological Survey of Ireland, and now Director of the Geological Survey in Bengal, &c.

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the naturalist of the living Sertularia. With the Oldhamia abundant traces of Annelides, similar to those of the Longmynd, have recently been found by Dr. R. Kinahan.

These, then, are the only signs of former life we have yet become acquainted with, after the most assiduous researches in the basement deposits of such vast dimensions, which are often, I repeat, less altered than much younger rocks replete with organic remains. Attention has been first called to the structure of the Longmynd, because, after many years of labour, this mountain is ascertained to be by far the thickest mass underlying those fossil-bearing Silurian deposits, which commence with the Stiper Stones of the same typical district.

FOSSILS (2).

Oldhamia antiqua, from Carrick MacReilly, Ireland.

(Remains of Fucoids are occasionally found with this fossil.)

The diagram given at p. 24 is taken from one of the several sections in which this order of succession was first illustrated before the Geological Society. (See also Sil. Syst. pl. 32).

A second diagram, reduced by Mr. Aveline from one of the published large sections of the Geological Survey, and which will appear in the next Chapter, is a satisfactory confirmation of the views which, broached in 1833*, were reiterated in 1835†, when the term Silurian was first applied to all the strata overlying the Longmynd, and were finally and fully developed, with coloured illustrations, when the 'Silurian System' was published‡.

Let us next mark the same first clear steps in the geological series, in the accompanying sketch from North Wales, which, as worked out by the Geological Surveyors, indicates a succession similar to that which was first described in Shropshire.

In this well-known scene, the spectator is supposed to be looking up to the Pass of Llanberis, from the lower lake of that name; the heights of Snowdon being in the distance on the right hand. In the foreground, and on both sides of the ruined castle of Dolbadarn, the faces of the cliffs exhibit flexures of the oldest strata here visible.

* Proc. Geol. Soc. vol. i. p. 475.

† Phil. Mag. & Ann. of Ph. 1835, p. 46.

‡ The 'Silurian System' was really issued in 1838, though 1839 is on the title-page. In proof of this, see Lyell's Elements of Geology, 1838, in which the leading data of the Silurian System are quoted from my work.

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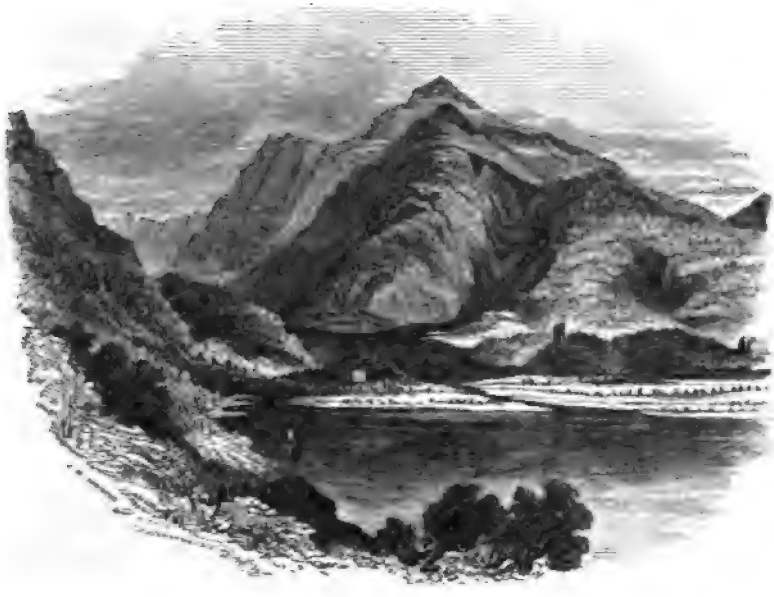
These are the purplish and grey slaty rocks, 1, of the previous sections, whose structure and relations in North Wales have been so well described by Professor Sedgwick. Containing the best roofing slates in the world*, and subordinate courses of grit, with rocks



PASS OF LLANBERIS FROM THE LOWER LAKE.

of igneous origin intermixed, they are seen to fold over and plunge to the E.S.E., so as to pass under the great and massive succession of schists, which constitute the distant heights of the Snowdon range. The reader will observe, that faint slanting lines have been introduced into the drawing to represent this ascending order, which the geologist can observe for himself, as he examines the sides of the valley in passing from the unfossiliferous slaty rocks of Llanberis, up to the overlying strata (2^a, 2^b, 2^c, of section below the map), which, by their imbedded organic remains, are known

* The slates of Llanberis lie in the masses to the left hand of the foreground, and are the property of Mr. T. Assheton Smith. Thence they range to the extensive quarries of Colonel Douglas Pennant, M.P., on the N.N.E. A very instructive diagram, representing the curves of the original strata at Llanberis, and the manner in which they are traversed by planes of slaty cleavage, is given by Professor Sedgwick, Quarterly Journal of the Geological Society of London, vol. iii. p. 138. For a correct acquaintance with all the faults and fractures of these rocks, the geologist will, of course, consult the subsequently published maps and sections of the Government Surveyors.

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to be of Lower Silurian age. In short, the rocks in the foreground stand in the place of the Longmynd, whilst the overlying or distant masses are the equivalents of the Stiper Stones, Shelve, and Corndon of the previous section, and even of the Caradoc Sandstone of Shropshire.

A like succession, and much clearer as regards the exposition of the fossils of the next overlying zone, is seen near Tremadoc on the north, and Barmouth on the south side of the hard Cambrian rocks of Harlech, which represent the upper portion of the Longmynd series. There, they also pass under the lowest member of the Silurian rocks—the Lingula Flags, or equivalent of the Stiper Stones—as explained in a diagram prepared for me by Professor Ramsay, for which see the next Chapter.

The generalized coloured section at the bottom of the annexed geological map, also prepared by Professor Ramsay, who, with his associates, Jukes, Aveline, and Selwyn, established the important identification of the slaty rocks of North Wales with their unaltered equivalents in the Silurian Region, will at once render the subject intelligible to the reader (see Preface). In the two fundamental masses of the Longmynd, on the east, and of Llanberis and Harlech, on the west, are represented, therefore, the oldest sedimentary rocks of England and Wales*.

Rocks similar in character to those of the Longmynd, Llanberis, and Harlech, and rising out, like them, from beneath all the Lower Silurian rocks, occur also at and near St. David's in South Wales. There again, as in North Wales, no fossils have been detected in them, but they are conformably overlaid, according to recent observations made by Mr. Aveline†, as in Shropshire and Wales, by strata in which the earliest conspicuous groups of animals have been detected. These British examples are well supported by an analogous succession in Bohemia, where M. Barrande has indicated the presence of an enormous mass of stratified rock apparently void of fossils, and forming the natural base of his Silurian basin of

* It is also worthy of remark, that in the long transverse section below the Map, extending in a right line over 90 miles of country, the *lowest rocks*, near each extremity (in Carnarvonshire as in Shropshire), are accompanied by mineralization of the strata. In both, copper and lead ores occur, and in parts of Merionethshire gold also appears in small quantities. The auriferous conditions of the Lower Silurian rocks of North Wales will be subsequently explained.

† Since the first edition of this work.

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Bohemia. In that region also, as in Scandinavia, the lowest or earliest traces of animal life occur in what that author terms the Primordial zone, or equivalent of the Stiper Stones and Lingula Flags of the British Isles.

In the next Chapter we shall open out these pages of the history of primordial life, so interesting to the naturalist, and in which we read off with precision how in other and younger strata accumulated beneath the primeval seas, different marine animals were deposited in each succeeding zone.

In concluding the subject of the Cambrian or basement rocks, a few words must, however, be offered, concerning two natural physical phenomena previously adverted to, by which the ancient deposits we are now considering, have passed, in North Wales, into states so very different from their condition in the Longmynd.

Slaty Cleavage.—The lowest rocks of North Wales are often, as before mentioned, in the condition of true slates. In this respect they present a very different aspect to the strata of the same age which constitute the Longmynd. For, although it was remarked in the 'Silurian System' (p. 258), that the Cambrian rocks of the Longmynd had more of a slaty character than any of the overlying deposits of the Silurian region, I pointed out that such cleavage was rude, irregular, and indeed apparent upon a large scale only. The materials composing the rocks of the Longmynd and the north-western part of Carnarvonshire are, however, essentially the same. In both, very fine sand and mud, chiefly of purplish and greyish or greenish colours, have been accumulated in countless thin laminæ of varying colours, with here and there an interstratified, coarser, and more gritty bed. They are further surmounted in both tracts by the lowest band of Silurian strata, containing the same fossils, whether in Shropshire, Carnarvonshire, or Pembrokeshire. But still the Welsh rocks differ strikingly from their Shropshire equivalents. The latter, when struck by the hammer, invariably break up along their original lines of stratification, like all ordinary sedimentary rocks; whilst the North Welsh strata of the same age have been so affected by a distinct determination of the fine particles of mud and sand of which they were originally composed, that they will split only into countless thin, hard plates, which cut across the original beds, and are all precisely parallel to each other, or in other words, into true roofing

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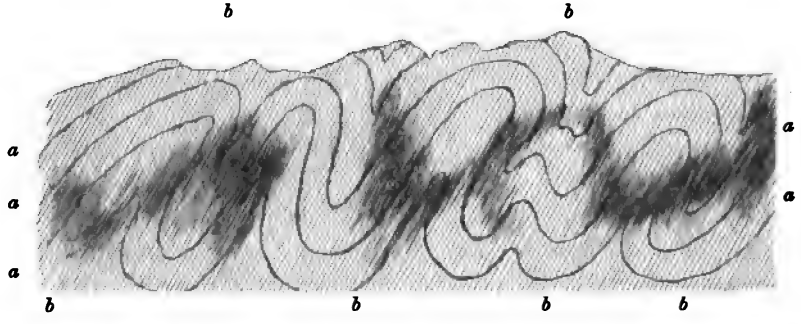
slates. This diagram will explain the distinction between original deposition, as indicated by the stronger curvilinear lines (*a a*), and the superinduced slaty and finer cleavage lines (*b b*), to which the weathered and the jagged edges of some of the mountains of Wales are frequently due.



SLATY CLEAVAGE AND BEDDING.

a. Strata or beds in undulation. *b*. Lines of cleavage. (The dark tint represents the portions of a mountain in which the layers of deposit and lines of cleavage coincide.) From Sil. Syst. p. 400.

To whatever force you subject the rock so affected, it will only break in the direction of the fine plates, or in other words, along the lines of slaty cleavage (*b b*). Whilst, to the geologist, the original layers of deposit are apparent, as marked by grey, purple, and greenish-coloured different laminæ (*a a*), the unpractised observer is easily deceived (like many geologists of the old school), and often mistakes these slaty plates for lines of stratification.

To Professor Sedgwick is justly assigned the merit of having first taught the true distinctions between slaty cleavage and stratification, and his valuable observations have had a wide application. For, this slaty impress has affected not only the oldest rocks of Carnarvonshire, where the finest slates are obtained, but also most of the overlying Silurian formations in Wales; whilst, in the original Silurian region, the same rocks are, as before said, exempt from it. Slaty cleavage prevails also through the younger schists of Devonshire, and, in the sequel, we shall have to note how it has been impressed upon schistose masses of the Carboniferous age. In short, although this structural arrangement was, in the early days of geology, looked upon as an indication of the great antiquity of the rocks in which it prevailed, and thus led to serious mistakes, the phenomenon is now known

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to be one which in Britain re-occurs throughout the Paleozoic rocks up to the Carboniferous inclusive.

Those who wish to be better acquainted with this striking phenomenon will do well to consult, in the first instance, the excellent memoir of Sedgwick, who, distinguishing, as before said, cleavage from stratification, referred this mighty change in the strata to some grand chemical operation in which heat and electricity were probably combined; or, in the words of that author, "crystalline or polar forces have re-arranged whole mountain-masses, producing a beautiful crystalline cleavage passing alike through all the strata*."

Subsequently, Professor John Phillips† and Mr. Daniel Sharpe‡ led the way in propounding another theory, the chief feature of which has been ably sustained and illustrated. Observing that the fossil shells entombed in certain slaty rocks of Wales, Westmoreland, and Devonshire were distorted in directions athwart the original layers of deposit, they inferred that the planes of cleavage which had so deformed the shells had mainly resulted from mechanical forces compressing the sediment at right angles to the lines of cleavage. Mr. Sharpe also, in further illustrating this subject, agreed with Sedgwick in regarding the phenomena of cleavage as being due to the action of some unknown and peculiar crystalline force.

Sorby, adopting the mechanical portion of this view, demonstrated its truthfulness§ by a series of ingenious experiments, clearly showing how the numerous flattish unequiaxed particles of the ancient mud and sand, out of which slate has been formed, had in all cases aided the great cause, or lateral compressing force, in producing cleavage.

Adhering exclusively to the mechanical theory, Tyndall‖ has recently farther developed the subject in a clear and experimental lecture, delivered at the Royal Institution. He differs from Sorby in believing that the production of cleavage was unaided by the shape of the particles in the rock, but was caused by the extension,

* Trans. Geol. Soc. Lond. 2nd Ser. vol. iii. p. 477.

† Rep. Brit. Assoc. 1843, Sect. p. 60.

‡ Quart. Journ. Geol. Soc. Lond. vol. iii. p. 74; and vol. v. p. 111.

§ Edinburgh New Phil. Journ. vol. lv. p. 137; Phil. Mag. 4th Ser. vol. xi. p. 20; *ibid.* vol. xii. p. 127.

‖ Phil. Mag. 4th Ser. vol. xii. p. 35; *ibid.* p. 129.

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under pressure, of the minute interstitial cavities which must exist in even the most finely levigated mudstones.

Passing over certain slight differences, these authors, as well as Professor Phillips, agree essentially in affirming, that cleavage is due to mechanical causes, or that slates are compressed rocks.

Whilst it is beyond my present object to dilate upon the forces originating a phenomenon, which, however it may be explained, throws no light upon the age or order of the strata, I might be permitted to suggest, that the geologist may, with profit, follow Sharpe, in accepting the suggestions of Sedgwick, and in endeavouring to combine them with the purely mechanical theory of Sorby and Tyndall.

If the last-mentioned authors have succeeded (as I think they have) in demonstrating that powerful lateral pressure was a main cause in the formation of slates, I am disposed to agree with Sharpe, that this cause *alone* could scarcely have produced such results as we see in the wonderfully minute parallel cleavages of a whole mountain-chain, had not the rocks at the same time been cogently affected, as Sedgwick supposed, by such forces as heat and electricity, combined with vapour and great lateral pressure*.

Not dwelling longer, however, upon this physical problem, I would remind the reader, that, once having obtained a clear insight into the distinctions between cleavage and stratification, as first pointed out by Sedgwick, the geologists who have long and patiently laboured in the Welsh mountains have been enabled to trace the symmetry of deposits, whose slaty composition, and frequent perforation by igneous rocks of various characters, had veiled them in an obscurity, from which their equivalents in Shropshire, Herefordshire, Radnorshire, &c., or the typical region of Siluria, are almost entirely exempt.

Metamorphic Rocks of Anglesea.—It has been stated that there are no rocks in South Britain of more remote age than the basement sediments which occupy the Longmynd and the parts of North and South Wales already spoken of. For a long time, indeed, it was believed†, that the schists and quartzose and felspathic rocks of the

* The reader who desires to be acquainted with all the phenomena relating to this difficult subject, including the foliation of rocks, must also consult two other important works, viz. 'Geological Observations in South America,' p. 163, by C. Darwin, and D. Sharpe's 'Researches on the Symmetry in the Arrangement of the Planes of Cleavage over large areas.' Phil. Trans. 1852, p. 445; and Journ. Geol. Soc. vol. iii. p. 87.

† See the Geological Maps of England and Wales, by William Smith and Greenough, and even the last edition of

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Isle of Anglesea, judging from their crystalline character only, were more ancient than any of the masses of the adjacent mainland. Such, however, is not the case. The pre-existing rocks, out of whose materials were formed both the schists, sandstones, and gritty or pebbly strata of the Longmynd in Shropshire, and of the Llanberis, Bangor, and Harlech mountains in North Wales, and of St. David's in South Wales, have long ago subsided beneath ancient oceans, and have been covered over by the strata of which we now treat.

CONTORTED CRYSTALLINE SCHISTS AT THE SOUTH STACK LIGHTHOUSE, ANGLESEA.

Thus, it is ascertained, that the schists of Anglesea are simply an altered portion of the same slates and grits which constitute the base of the Silurian series of deposits in the adjacent counties of Carnarvon and Merioneth. In other words, the oldest strata of Anglesea have been altered at one spot into chlorite and mica-schist, in another into quartz rock, accompanied by most extraordinary flexures of the beds*. Agreeing with my friends of the Geological Survey, that

the latter, published in 1839; as well as the 'Outline of the Geology of England and Wales,' by Conybeare and Phillips.

* The reader will find an admirable account of some of the metamorphosed strata of Anglesea, and their contortions, in a memoir by Professor Henslow, published as far back as the year 1822. This work, which may still be read with very great profit, was a truly remarkable proof, at that early date, of the geological powers of the author. Transact. Cambridge Phil. Soc. vol. i. p. 15.

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this is a true explanation of the case, a small sketch is here annexed, to indicate the amount of curvature which these metamorphosed strata have undergone, as seen at the promontory of the South Stack Lighthouse, near Holyhead.

These contorted, crystalline rocks of Anglesea, with their intruded granites, are overlaid by, and associated with stripes or patches of different paleozoic rocks, of Silurian, Devonian, and Carboniferous age; thus forming a network, which the most experienced geologist might have difficulty in unravelling. Their outlines, generally laid down in Greenough's Map of England, are now, indeed, very accurately defined in the sheets of the Government Survey. The whole of the bands have a direction or strike from S.S.W. to N.N.E., as may be seen in the annexed Map.

No sooner, however, do we pass the Menai Straits, and advance eastwards towards the west flank of the mountainous range of Snowdon, than we find huge buttresses of very ancient grit, schist, slate, and sandstone, having the same direction, from S.S.W. to N.N.E., in which, though their sedimentary character is obvious, and though they have not been so much altered as in Anglesea, but one obscure fossil has been detected throughout a thickness of many thousand feet. Now, all these deposits, whether in a metamorphic state in Anglesea, or in a slaty condition on the mainland, are the true basement rocks of England and Wales. In other words, these oldest rocks of North Wales are the equivalents of the strata of the Longmynd Hills, which were first described as types of that 'greywacke' which was shown to form the base of the original formations of the Silurian system*. (See general section below the Map.)

It is to the lowest of these sedimentary rocks of the Silurian Region and North Wales, whether scarcely at all changed in the Longmynd, in a slaty condition in Carnarvonshire, or quite metamorphosed in Anglesea, that the term Cambrian was restricted by the late Sir H. De la Beche and his associates the Geological Surveyors; and I naturally adhere to a definition which, as above shown, coincides precisely with my earliest development of the order of succession.

* See above, p. 23, *note*.

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CHAPTER III.

LOWER SILURIAN ROCKS.

ASCENDING PASSAGE OF THE STRATA FROM THE STIPER STONES TO THE LLANDEILO FLAGS, AS PROVED BY PHYSICAL AND ZOOLOGICAL CHARACTERS IN THE TYPICAL TRACT OF THE SILURIAN REGION.—SIMILAR ORDER OF STRATA IN WALES FROM THE LINGULA FLAGS UPWARDS.—THE LLANDEILO ROCKS AND THEIR FOSSILS AS EXHIBITED IN SHROPSHIRE.—THE RANGE OF THE SAME FORMATION WITH ITS CHARACTERISTIC FOSSILS THROUGH WALES.—THE SEPARATION OF THE LLANDEILO ROCKS FROM THE CARADOC OR BALA FORMATION BY INFRAPOSITION AND FOSSILS.—THE RANGE OF GRAPTOLITES.

LET us now continue our survey by reverting to that district of Shropshire in which, as has been shown, the fundamental rocks are more largely developed than in any other part of England and Wales, by examining the fossiliferous strata which, resting in conformable apposition upon the upper ledges of the Longmynd, have, from the period of my earliest researches, been classed as Silurian. The lowest of these bands is well displayed in the ridge called the Stiper Stones, than which there are few more striking features in the physical geography of the British Isles. Trending in a broken, mural line from N.N.E. to S.S.W., these stony masses appear to the artist like insulated Cyclopean ruins jutting out upon a lofty moorland ridge, at heights varying from 1500 to 1600 feet above the sea. On reaching the summit of this barren height, the traveller sees below him, to the west, a rapid slope, and beyond it a picturesque hilly tract, the strata of which are laden with Lower Silurian fossils, and diversified by a variety of rocks of igneous origin. In short, he has then within his view the original type of formations which, raised to greater altitudes, and affected by a

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slaty cleavage, occupy large, mountainous districts in Wales. The annexed sketch of a portion of this tract, where the undulating grounds are composed of the Llandeilo formation, with some interstratified igneous rocks, and where the eruptive mass of the Corn-

LOWER SILURIAN, AND BEDDED TRAP, TRAVERSED BY ERUPTIVE ROCKS; THE CORNDON MOUNTAIN IN THE DISTANCE TOWARDS THE NORTH.

(From Sil. Syst. p. 271.)

Lower Silurian tract west of the Stiper Stones (Shelve, &c.).

don occupies the highest point, conveys a fair idea of the contours of the old Silurian country which is about to be described.

The geologist who becomes familiar with the protruding bosses called the Stiper Stones perceives that they are outstanding fragments of a thick band of siliceous sandstones. Though in parts veined, altered, and fractured, and occasionally passing into crystalline quartz rock, they yet form an integral portion of the overlying schistose formation; whilst fragments of the shells called Lingulæ occur in them.

Extending from Pontesbury near Shrewsbury on the N.N.E. to Snead near Bishop's Castle on the S.S.W., or for a distance of upwards of ten miles, these siliceous rocks, though subjected to several transverse breaks which have given slightly divergent directions to portions of the chain, maintain steadily their relation to the Cambrian or Longmynd series beneath, and to their overlying associated Silurian strata; being conformably underlaid and overlaid by dark grey schists. In fact, they constitute the natural

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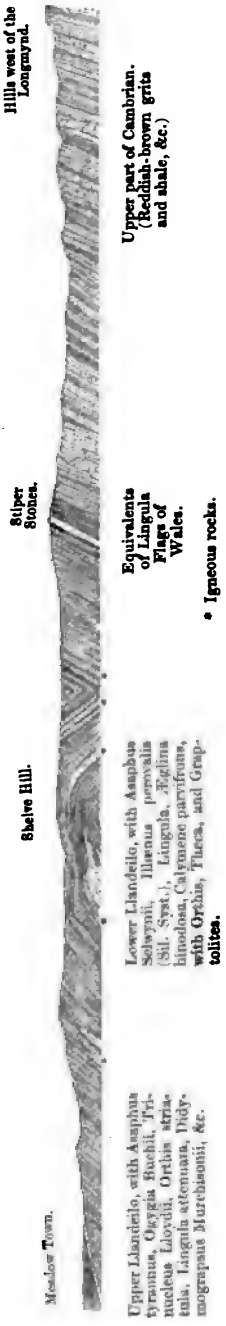
SECTION SHOWING THE RELATIONS OF THE LOWER SILURIAN ROCKS IN THE WEST OF SHROPSHIRE.



base of the Llandeilo rocks of the Shelve and Corndon district, into which they graduate upwards, dipping at high angles to the N.N.W., as represented in the previous general section, p. 24, and also in this diagram, taken from one of the published sections of the Government Survey.

In the peaks known as the Stiper Stones, the rock has all the appearance of having been altered by the influence of the heat which must have accompanied the evolution of those igneous rocks (chiefly greenstone) which occur on both sides of the ridge*. When most crystalline, it is often intersected by veins of vitreous quartz, and on the broken and weathered fragments are exposed numerous small white facets of quartz crystals, presenting a vivid contrast to the dull brown heath over which they are strewn. In the first of the accompanying sketches†, in which the spectator is looking along the ridge to the S.S.W., the valley on the left hand has

* Several small additional bosses of greenstone were recently detected by Mr. Gibbs on the eastern side of the ridge, and these I examined on my last visit to this interesting tract (September 1856).

† From a drawing by the Rev. John Parker of Sweeny.

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been excavated in the uppermost strata of the Longmynd rocks not far to the north of Linley.

THE EASTERN FACE OF THE STIPER STONES.

In the following sketch, on the contrary, the protruding rocks are the culminating portions of the rapid slope before adverted to, the strata of which form an integral part of the Lower Silurian Rocks.

THE WESTERN FACE OF THE STIPER STONES.

The altered condition of these rocks is again instructively exhibited at Granham, to the north of Vessons Coppice, near Pontesbury, where the chief mass is white and crystalline, much fissured,

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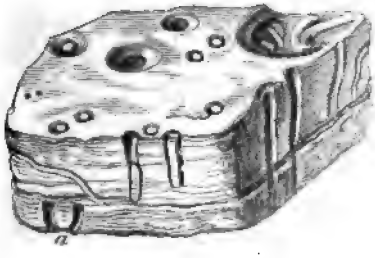
and penetrated by a vein charged with anthracite, small flakes of which are disseminated through the rock. In following these ledges of quartz rock, whether to N.N.E. or S.S.W., we find them passing into coarse grits and siliceous sandstone. At Nils Hill, close to Pontesbury, where the ridge has subsided to a low elevation, the rock loses much of its altered character, and, being largely quarried as a road-stone, is much more clearly exposed than in the higher parts of its range. The strata dip at the high angle of 60° to 70° to the W.N.W., and are there exhibited in a thickness of from 800 to 1000 feet. The beds, varying in dimensions from a few inches (many of them being 'flagstones') to two and three feet, are separated by way-boards of sandy shale, and the lower dividing laminæ are here and there composed of greenish and white unctuous clay.

On the surface of some of the numerous flag-like beds are broad wavy undulations, and also the ripple-marks so common to many sandy deposits. Together with these are also ramose and twisted forms, some of which are probably the casts of seaweeds, and amongst them is the Cruziana or Bilobites (d'Orb.)*.

Mr. Salter has recently satisfied me, that some of the more tubular-shaped cavities and cylindrical bodies are the borings and casts of worm-like animals, and may well represent the Scolithus linearis of Hall, a fossil which characterizes the Potsdam Sandstone, or lowest Silurian rock of North America. The vertical tubes, curved

FOSSILS (3). ANNELIDE-BURROWS IN THE STIPER STONES.

A mass of sandstone, with the vertical tubes of sand-burrowing Annelides (Scolithus linearis of Hall).



The burrows have two apertures, and are connected below by a loop-like tube, as at *a*.

at their base, and their trumpet-shaped openings are well preserved, and of a size equal to those of the common lob-worm of our coasts. These appearances are represented in the accompanying woodcut.

* See 'Silurian System,' pp. 284–5, for further details respecting the structure and relations of these rocks.

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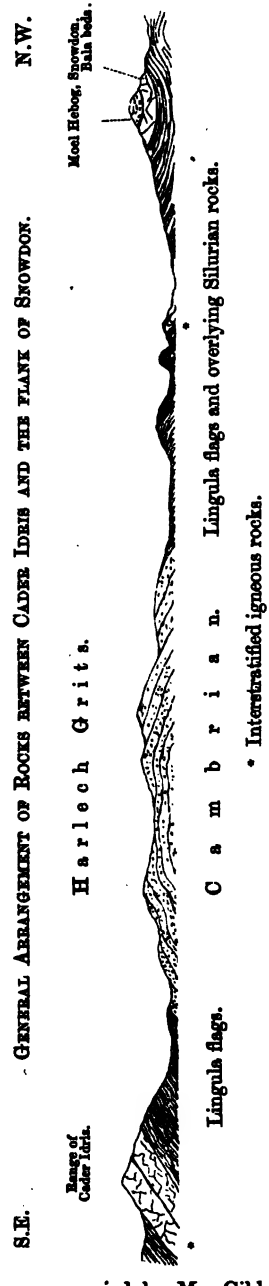
GENERAL ARRANGEMENT OF ROCKS BETWEEN CADER IDRIS AND THE FLANK OF SNOWDON.



Numerous fragments of Lingulæ having been recently discovered, both in the beds immediately beneath, and in those forming the upper part of this siliceous rock*, there can be little doubt (especially as they overlie the rocks of the Longmynd, and graduate upwards into the great mass of the Lower Silurian Rocks) that the band of the Stiper Stones represents the Tremadoc Slates of North Wales, in which, and at the same geological horizon, Lingulæ and other fossils occur, in strata separated by a distance of sixty miles across their strike. It is well to observe that the finely micaceous sandy shale or schist which underlies the more siliceous portion of the series has a great similarity in composition to the beds above the quartz rocks. In short, the whole of these beds are so knit together, and pass so imperceptibly into the superior strata, that no boundary-line can possibly be drawn upon a map, between the rocks composing the Stiper Stones, and the hard, grey, arenaceous, flag-like shale into which they graduate; the latter, too, containing organic remains, some of which belong decidedly to the Llandeilo formation. (See 'Silurian System,' pp. 268, 270, 274, 280, 283 *et seq.*, and pl. 32. figs. 1, 2, & 3.)

The special Lingula of the Stiper Stones has, it is true, been detected in numerous

* These fossils, and many others in the beds immediately overlying the Stiper Stones, were found by Mr. Gibbs, the able collector of the Geological Survey, in August 1856. During this search, I re-examined the northern portion of my old ground, accompanied by Mr. Gibbs, and had the satisfaction to detect some of these Lingulæ, as well as siliceous flagstones with Scolithi, in an integral part of the Stiper Stones at Eskridge, near Lord's Hill.

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small fragments only; and, whilst the rock unquestionably occupies the same stratigraphical position as the Lingula Flags of Wales, yet, judging from the fragments, it appears that the species of the Stiper Stones is not the prevalent L. Davisii of the Welsh slates. When, however, we recollect the extent to which the strata of the Stiper Stones have been altered, and the rarity and broken condition of the Lingulæ detected in them, the specific difference of the one as yet met with is perhaps of no great importance; for, as we shall presently see, there are, in Wales, other and undescribed forms of Lingula associated with the L. Davisii.

Again, it is to be borne in mind, that the Stiper Stones are not less than sixty miles distant from their equivalents near Tremadoc, and that in being carried so far to the east, the deposit has become much more siliceous. The plain facts, however, are, that a Lingula zone in Shropshire, as in Wales, lies conformably upon the Cambrian or Longmynd rocks, and in both tracts, as will soon be shown, gradually passes up into beds charged with the same Lower Silurian species of organic remains.

Lingula Flags of Wales.—The Lingulæ which particularly characterize this zone were for a long time unknown even to Professor Sedgwick, who had described the position and mineral character of the slates in which these fossils occur. They were first discovered near Tremadoc by Mr. Davis in 1845; and, from their general similarity to some forms of the genus found abundantly in well-known Silurian rocks, he then termed the slates which contained them Silurian*. The classification followed in this work, which groups the Lingula (and Agnostus) Flags of North Wales with the Lower Silurian rocks, was first adopted by the late Sir Henry De la Beche and his associates of the Geological Survey, and was so published in all their works. M. Barrande, M. de Verneuil, and the explorers of the paleozoic rocks and fossils on the continents of Europe and America have, indeed, adopted the same classification.

The opposite sectional diagram, drawn by Professor Ramsay, gives the general ascending succession both to Moel Hebog on the flanks of Snowdon on the north-west, and to Cader Idris on the south-east. It shows how on each side of an axis or dome of the Cambrian rock of Harlech, or the equivalent of the upper portion of the

* Quart. Journ. Geol. Soc. Lond. vol. ii. p. 70.

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Longmynd, there is a zone of Lingula Flags, and how each of these is in its turn overlaid by other Lower Silurian deposits with interlaminated igneous rocks. The order in North Wales is therefore similar to that in Shropshire, as exhibited in the preceding woodcuts. The conformable passage upwards from the basement rock into the Lingula Flags, which is well seen in several other localities, is also here represented as observed at Barmouth.

b. Lingula schists with imperfect transverse slaty cleavage (white lines).
a. Grits and schists; Longmynd or Cambrian rocks.

The lower portion of the Lingula Flags in North Wales is, for the most part, a light grey and arenaceous schist with a glossy surface, which rests upon black slaty schist.

The chief fossil, a flat bivalve shell, the Lingula Davisii, as figured in the following woodcut (4. fig. 1), has a covering which is very horny, and only slightly calcareous; showing that its inhabitant was suited to the conditions of a sea whose bottom was composed of mud and sand, and which contained but little lime wherewith to supply the fabric of the thicker shell of other mollusca. It is, indeed, a remarkable fact, that in the vast thicknesses of the inferior or unfossiliferous greywacke before adverted to (p. 23), there is little or no lime, and scarcely the trace of a shell; whilst in these the lowest strata in which calcareous matter is apparent, it has only occurred in such small quantities as to afford a very thin testaceous covering to the few animals of this early zone of life. We shall presently see that when the Silurian fauna became abundant, as in the next overlying strata, it was accompanied by a corresponding development of lime, which served as the material for the construction of the shells of the imbedded mollusks.

In ascending through the different stages of the Silurian system, it will also be seen that different species of the genus Lingula occurred most frequently at those intervals in which there was a return to similar sedimentary conditions, *i. e.* whenever the muddy sea-bottom was only slightly impregnated with lime.

Trilobites, or the earliest crustaceans, abound infinitely more

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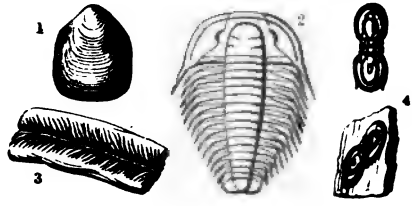
in the Silurian than in the next overlying system of rocks, and the earliest which the labours of geologists have brought to light in Britain are Agnostus, Paradoxides*, and Olenus; a species

FOSSILS (4). LINGULA FLAGS, NORTH WALES.



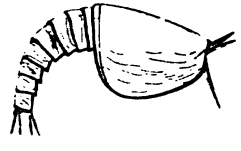
1. Lingula Davisii, M'Coy.
2. Olenus micrurus, Salter.
3. Cruziana semiplicata, Salter.
4. Agnostus pisiformis, Linn., both of the natural shape and distorted by cleavage.

of the last-mentioned genus, O. micrurus, Foss. 4. f. 2, having been found associated with the Lingula and Agnostus in this zone as it appears in Wales.

Besides these fossils, a new crustacean of the Phyllopod or Stomapod† tribe was found,—Hymenocaris vermicauda. A figure of this crustacean is here given, from specimens in the collection of the

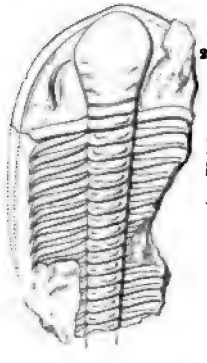
FOSSILS (5). LINGULA FLAGS, N. WALES.

1. Hymenocaris vermicauda, Salter. A phyllopod or stomapod crustacean.



Restored outline, from several nearly perfect specimens from Dolgelly.

2. Paradoxides Forchhammeri, Angelin? Locality unknown; probably from Pen Morfa near Tremadoc, N. Wales.



Black Schists of N. Wales.

Geological Survey. It is plentiful at Dolgelly and Tremadoc, in North Wales, associated with Lingula Davisii. Tracks of Annelides also prevail, as in the rocks beneath and above the Lingula Flags, and sometimes are of considerable size.

* Only one species of Paradoxides (Foss. 5. fig. 2) has yet been found in Wales; although the specimen is imperfect, Mr. Salter believes it to be identical with P. Forchhammeri, of the alum slates of Andrarum in Scania.

† See Mr. Huxley's observations on the Affinities of some of the Silurian Crustacea, Quart. Journ. Geol. Soc. vol. xii. p. 34.

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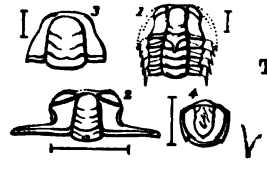
In beds of the same age, near Bangor, have been also found two kinds of fucoids, one of which is, perhaps, the Chondrites acutangulus, M'Coy; the other is a new species of the curious genus Cruziana (Bilobites, d'Orbigny), Foss. 4. fig. 8.

With the Lingulæ, of which the L. Davisii is most abundant (the L. lepis, n. sp., being rare), there are associated in the lowest courses of these flags several other fossils, of which the Agnostus pisiformis is much the most frequent; being also characteristic of this same band in Bohemia and Scandinavia. To the eye of the field geologist, this little crustacean seems to be scarcely distinguishable from the Agnostus of the overlying Llandeilo Flags (Pl. III. fig. 8), in which deposit, as will presently be seen, there is a similar association of Lingula and Agnostus. The L. Davisii and A. pisiformis are the common species in the Lingula Flags. The other fossils above quoted (Paradoxides and Olenus) are rare in Britain*.

Small species of Olenus are also found in the lowest known fossil strata of another British tract. In the black schists on the western flanks of the Malvern Hills, strata which I had termed Lower Silurian,

FOSSILS (6).

1. Olenus humilis, Ph.
2. O. bisulcatus, Ph.
3. O. scarabæoides, Wahl.?
4. Agnostus pisiformis, L.



Trilobites from the Black Schists of the Malverns.

Professor Phillips detected three species of this genus, viz. O. humilis, Foss. 6. f. 1; O. bisulcatus, f. 2; O. scarabæoides (O. spinulosus, Ph.), f. 3. To these my late friend Mr. Hugh Strickland made the interesting addition of the Agnostus pisiformis, Linn.,

* See Angelin's 'Palæontologia Scandinavica,' Pars I.

Geologists who desire to consult a clear and comprehensive view of the equivalents of the British zone of the Lingula Flags, or Stiper Stones, as well as the whole group of the Silurian rocks as exposed in Bohemia and Scandinavia, should read a memoir entitled 'Parallèle entre les Dépôts Siluriens de Bohême et de Scandinavie,' by M. Barrande, in which that author shows the exact parallelism of all the beds of his Silurian basin of Bohemia with those of Scandinavia, as indicated in the 'Regiones' (or stages) of M. Angelin. By reference to the existing distribution of submarine animals, he satisfactorily explains why the species of the crustaceans and other animals, which are detected in Silurian tracts not distant from each other (the strata of which were simultaneously accumulated), often differ, though the generic types agree. This interesting topic, bearing on the ancient hydrography of Europe, will be reconsidered in the concluding Chapter.

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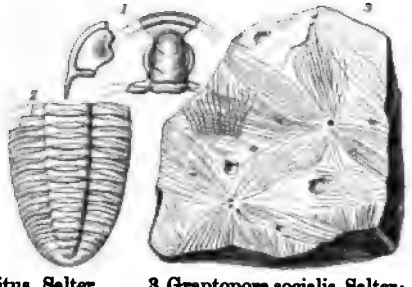
Foss. 6. f. 4, a fossil known in the oldest Silurian schists or alum slates of Sweden. And, associated with it, Olenus is found in the same fossiliferous stratum in Scandinavia, resting, as at Malvern, on a sandstone in which no other remains have been detected except fucoids. Again, in Bohemia, on the same low horizon of life, we meet with Agnostus, Paradoxides, Conocephalus, and other trilobites, several of which have not yet been discovered in our islands*. (See Chap. 13.)

Upper Lingula Flags.—The researches of Mr. Salter amid these older rocks of North Wales have enabled him to distinguish the zone just described from another and superior band, intimately connected therewith, but containing some new species. This upper portion of the Lingula Flags is a dark grey or blackish schist with thin layers of grit, which, whilst it also contains the Lingula Davisii and the Agnostus, is characterized by other fossils, such as Conocephalus invitus (Foss. 7. fig. 1); Ellipsocephalus? depressus (fig. 2); Graptopora† socialis (fig. 3); together with a small Orthis and Olenus alatus, Beck, a Scandinavian species.

These fossils occur at Penmorfa and Y-Wern near Tremadoc, and along the base of Moel-y-Gest; where a black slaty layer

FOSSILS (7). UPPER PART OF THE LINGULA FLAGS, N. WALES.



1. Conocephalus invitus, Salter.
2. Ellipsocephalus? depressus, Salter.
3. Graptopora socialis, Salter; a Bryozoon allied to Fenestella, and the oldest yet known of the group.

has been detected in this zone, whose surface is covered by the Graptopora above noted, showing an undisturbed state of the former

* See the admirable work of M. Barrande, 'Le Bassin Silurien de Bohême,'—a monument of the talent and perseverance of the author, whilst residing in a foreign land, and exhibiting a surprising combination of palæontological knowledge with an accurate delineation of rocks. It is a most remarkable and truly philosophical monograph.

† A newly discovered generic form, exceedingly interesting as showing a probable connexion between the Fenestellidæ and Graptolites. Its texture is horny.

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sea-bottom. Near Maentwrog and Ffestiniog the same bed has been traced, overlying the lighter-coloured and more arenaceous mass of the Lingula Flags, and, both by its darker colour, and by exhibiting for the first time, in the series of strata, a Bryozoon and an Orthis, together with the Agnostus pisiformis, it seems to be linked on to the lowest part of the Llandeilo Flags, into which it graduates conformably.

In South Wales, the Cambrian or Longmynd rock of St. David's is also seen to be overlaid, on the north-west and south-east, by a zone of flags containing the Lingula Davisii, which is well exposed in Whitesand Bay (see Map), and is there followed on the north-west by black schists, flags, and slates, representing the mass of the Llandeilo series. Thus, whether we examine North or South Wales, we ascend gradually from the same bottom rocks as those of the original Salopian or Shropshire tract*, through strata which afford the earliest well-defined remains of animal life.

Llandeilo Formation in Shropshire and adjacent part of Montgomeryshire.—Although this formation obtained its name from the town of Llandeilo in Carmarthenshire, where the greatest number of its characteristic trilobites were collected, let us first describe it in the district of Shropshire; since there is no portion of the British Isles where a clearer exposition can be seen of the ascending order from strata containing the earliest signs of former life up into deposits teeming with organic remains. The subjacent strata which we have been considering do not, indeed, rise to the surface at or near Llandeilo, and hence the description of the formation near that town is deferred.

During my early researches in Shropshire, I observed certain fossils within a few hundred paces of the Stiper Stones, but many more important organic remains near to that striking ridge have been recently detected. In addition to the clear and symmetrical order, which is there exhibited, we now indeed possess fossils for the perfect elucidation of each band, as we proceed upwards from the Stiper Stones to the other Silurian deposits (see the sections, pp. 24 & 39).

* The researches of my successors have confirmed my observation, that this district is the only one in the Silurian Region proper in which it is possible to observe strata of higher antiquity than the Llandeilo Flags.

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The strata into which the siliceous grits of the Stiper Stones graduate upwards are slightly micaceous, grey flagstones, usually weathering to a brownish colour, and alternating with more schistose and darker coloured beds. On the whole, they are of uniform texture, as seen in any of the deep combes which indent the western side of the ridge of the Stiper Stones*. Thus, in the transverse opening in Lord's Hill near the Snailbatch Lead Mine†, or in the deep hollows of the Crow's Nest, Black Hole, Mytton Dingle, and Perkins' Beech, the strata, being scarcely at all interfered with by igneous rocks, are observed to succeed each other with the utmost regularity; all having the same strike and dip as the Stiper Stones on which they rest. Of these transverse sections, that of Mytton Dingle is certainly the most expressive; for, in addition to the great depth of this combe, its northern side presents a series of lofty-pinnacled rocks, the beds of which are seen to dip symmetrically under each other to the W.N.W., through a thickness of not less than 3000 feet.

The points nearest to the Stiper Stones at which fossils have been collected, along the western face of the ridge, are on the slopes of Lord's Hill, near the adjacent Chapel, and at the heads of the combes called Mytton Dingle and Perkins' Beech. They are still more abundant, and the species more varied, in the dark, almost black, earthy slates that overlie these flagstones and form the rising ground to the east of the Bog Mine. The same beds are richly fossiliferous a little further south at Ritton Castle, at the mining ground of Cefn-y-Gwynlle to the west of the southern termination of the Stiper Stones called Heathmont, and at Disgwylfa near Snead. Similar fossils occur, and have been for some time known, in undulations of the same strata considerably to the west—as at the White Grit Mines.

Considering all these localities as belonging to one and the same zone, the organic remains exhibited in the following woodcut are

* See Section at p. 24; and Map of the Geological Survey, Sheets 60 and 61.

† The reader who desires to obtain information respecting the Lead Mines of this tract, which occur in these Lower Silurian rocks, must consult the 'Silurian System,' pp. 277 *et seq.* In this work my chief object is to present a clear idea of the age and sequence of the deposits. The associated igneous rocks, and the vast interpolated sheets of volcanic grit which begin to show themselves very low in the order of the strata, and particularly in this tract of Shropshire, will, however, be described in the next Chapter.

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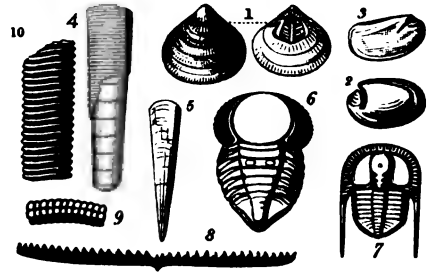
its dominant forms, and they have all, it will be observed, a true Lower Silurian *facies*.

FOSSILS (8). FROM THE WEST SIDE OF THE STIPER STONES.



1. Lingula plumbea, Salter. 2. Cucullella? anglica, id. 3. Redonia? complanata, id. 4. Orthoceras Avelinii, id. 5. Theca simplex, id. 6. Æglina binodosa, id. 7. Trinucleus Murchisonii, id. 8. Didymograpsus geminus, His. 9. Encrinite stem (the oldest known). 10. Orthoceras encrinale, Salter.

In enumerating these fossils it will be seen, that some valuable additions have been made to the few forms already described. Thus, to the Illænus perovalis of the 'Silurian System' (Pl. 23. f. 7), and the very characteristic species, Ogygia Selwynii (Foss. 9. f. 8) (fragments of which much resemble the O. Buchii), have been added a new species of Trinucleus, T. Murchisonii (Foss. 8. f. 7), and the very remarkable Æglina which, from its invariably presenting a double tubercle on its third body-segment, has been called Æ. binodosa. Among the mollusks, the commonest species is a Lingula, apparently special to this metalliferous district, and hence termed L. plumbea. Besides this, there are the well-known fossils, Orthis alata and O. calligramma (Sil. Syst.), and these are now seen to be accompanied by two remarkable new species of Redonia, or Cucullella (f. 2, 3); whilst the several species of Orthoceratites, to one of which Mr. Salter has assigned, at my request, the name of O. Avelinii (f. 4), are no less important augmentations of our knowledge. Again, among those characteristic Silurian animals the Graptolites, besides some previously recognized species, Diplograpsus pristis and Didymograpsus Murchisonii, we find both the divergent and reflexed varieties of the Didymograpsus geminus, a well-known Silurian species in Sweden and Norway. There is also a Fenestella, or Retepora?, which differs from the Graptopora above mentioned (p. 47), and is of an expanded cup-like form; there are also several other imperfect fossils.

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Other species, with some of the above-mentioned forms, are found in the equivalent strata in those parts of Wales to which attention will be soon directed.

On the western flank of the Stiper Stones, this, the lowest part of the Llandeilo formation contains many interstratified bands of igneous materials, being what were termed 'volcanic grit' when this tract was first described, but now more currently known under the term of 'Ashes.' Several striking courses of such rocks are exhibited at Cefn y Gwynlle and various other spots*. These, with bosses of igneous rocks of intrusive character, the chief mass of which is seen in the Corndon Mountain, as represented in the drawing, p. 38, will be described when the succession of organic life in the Llandeilo and Caradoc formations of various districts shall have been explained. Again, this district is eminently metalliferous, containing many lead-mines which have been worked from the time of the Romans. Such mineral features require more illustration than can be given to them in the present volume; and on this head, and for all local details respecting the igneous rocks, the reader is referred to the 'Silurian System.'

From these lower strata the observer ascends into a thick succession of flagstones of dark grey and light blue colours, in parts calcareous, such as those which compose the chief mass of the Llandeilo formation (Section, p. 24).

These beds abound in trilobites;—Asaphus tyrannus, Ogygia (Asaphus) Buchii, and Trinucleus being the most frequent; together with Lingulæ, Graptolites, &c. These and other characteristic fossils will be figured in a woodcut; they are also seen in Plates I. II. III. IV. V., taken from the 'Silurian System.'

The characteristic trilobites also occur abundantly in flagstones around the town of Llandeilo and the adjacent parts of Carmarthenshire and Pembrokeshire, as well as at Builth in Radnorshire, and near Llanrhaiadr in Denbighshire; but the beds in which they there lie do not exhibit the relations to underlying rocks which are so clearly exposed in this district of Shropshire.

Now, all the strata which are exposed from the Stiper Stones inclusive to the western edge of this Shelve tract, or to the villages of Chirbury and Meadowtown (Section, p. 39), and which, with

* See detailed Map of Geol. Survey, Sheet 60.

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the interstratified volcanic ashes, have been ascertained by the Surveyors to have a thickness of about 14,000 feet, were laid down as Lower Silurian in my earliest publications, from the year 1833 onwards. On the other hand, the fossils of North Wales, now known to be of the same age, had not then even been detected, much less described, although the strata of the tract we have been considering had been paralleled, by means of their principal organic remains, with the Llandeilo formation of Carmarthenshire.

The Llandeilo Formation in Wales.—Having indicated the relations of these 'Black Trilobite Flags' to the subjacent rocks in the typical district of the Silurian Region, let us next consider them in those parts of Wales where the formation is laden with the same characteristic fossils, and surmounted by other strata which are now ascertained to be the equivalents of the Caradoc Sandstone of Shropshire. In North Wales, strata similar to those which have been described on the west flank of the Stiper Stones (differing only by being in a slaty condition) exhibit a like passage from the Lingula Flags into the mass of the Lower Silurian rocks. There, the latter, with many slaty ash beds, occur beneath the great bands of the porphyritic rocks of Arenig and Ffestiniog, near Tremadoc*, and at Llanfaelrhys, S. of Carnarvonshire, at which places they contain the well-known Silurian fossils, Orthis calligramma and Diplograpsus pristis, two or three species of Lingula, and Ogygia Selwynii, the species characteristic of the beds on the west flank of the Stiper Stones†, with other trilobites, such as Asaphus affinis (M'Coy), a Trinucleus, and several new species figured in woodcut (Foss. 9. p. 53).

Some few of these, *e. g.* the two species of the new genus Angelina, together with Lingula Davisii and L. lepis, Salter, were found by their discoverer in the lowest beds of the zone; and he thinks they may be more accurately classed with the upper portions of the Lingula Flags. The Ogygia scutatrix, however, found with them, is of a genus as yet unknown in rocks lower than the Llandeilo Flags.

The chief mass of the Llandeilo formation is not well seen around the bases of Snowdon and Cader Idris, as surmounting the

* Termed 'Tremadoc Slates' by Professor Sedgwick in 1847. None of their fossils, however, were described until the year 1851; indeed the greater part were found by Mr. Salter in 1853.

† Asaphus Selwynii, Salter, Report of the British Association, 1852, Belfast; Transactions of the Sections, p. 57. This species may possibly prove to be identical with the A. Corndensis (Sil. Syst.), obtained from the same district.

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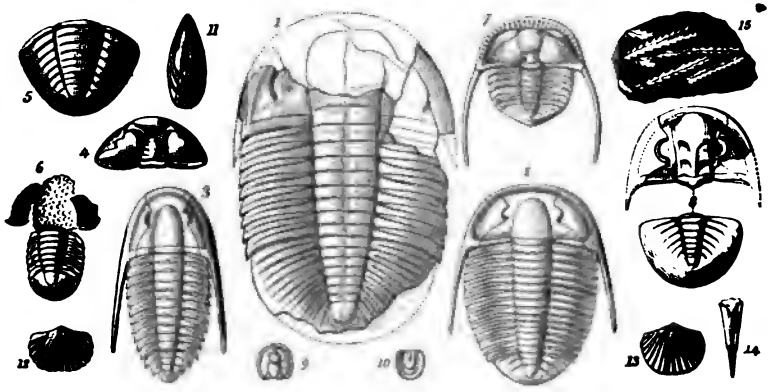
older strata or Lingula Flags. Stratified igneous rocks with slates are there so dominant throughout a vast thickness, that the type-fossils, such as Asaphus tyrannus and Ogygia Buchii, have not yet been detected, although some associated species of shells occur rarely.

FOSSILS (9). FOSSILS OF LOWER LLANDEILO ROCKS (N. WALES).



1. Ogygia scutatrix, Salter. 2. Angelina Sedgwickii, id. 3. A. subarmata, id. 4. Calymene parvifrons, id. 5. Homalonotus bisulcatus, id. 6. Æglina grandis, id. 7. Trinucleus Gibbsii, id. 8. Ogygia Selwynii, id. 9. Agnostus pisiformis, Wahl. 10. Agnostus, n. sp.? 11. Lingula Davisii, M'Coy, in a compressed form. 12. Orthis calligramma, Dalm. 13. O. remota, Salter. 14. Theca vaginula, id. 15. Diplograpsus pristis, His.?

On the eastern flank, however, of the Berwyn Mountains, just as at Llandeilo in South Wales, the formation, though slaty, is also characterized by its organic remains, and is seen (Section, p. 62) to pass under other and more arenaceous rocks which form the mass of the Caradoc formation, with which the limestone rocks of Bala in North Wales have been identified. The clear separation of the Llandeilo from the overlying formation of Bala, with which it has been till now associated, will be dwelt upon in the sequel. In the Shropshire district, where the fullest examples of the lowest Silurian deposits are exhibited, the reader will see, by reference to the coloured Map, as well as to the sections previously given, that the Llandeilo formation is subtended on the north, south, and west by younger Silurian deposits, with which the older rocks are abruptly collocated. To this break, as well as to other discordances of position, attention will be called in other Chapters; it being now desirable to conduct the reader to spots where he may clearly see that the flags containing the Asaphus tyrannus, with Graptolites and other fossils, and identical in their contents and character with the strata of the

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Shelve tract in Shropshire, are conformably overlaid by masses, usually more arenaceous, which represent the great body of the Caradoc or Shelly Sandstone of the Silurian classification.

In South Wales, the same ascending order that we have followed from the western flank of the Longmynd and in North Wales has recently been observed, and it may be conveniently noticed here.

In the environs of St. David's, as before said, purple and green schists and hard grits, formerly identified with the rocks of the Longmynd, and containing traces of fucoids *, are overlaid in Whitesand Bay by slaty flagstones (see Map), in which Lingula Davisii occurs, the same as at Tremadoc in North Wales. These, the lowest fossiliferous strata of the tract, graduate upwards into dark-coloured schists and slates, such as those observed on the west flank of the Stiper Stones; some of the best preserved trilobites of the lower portion of the Llandeilo Flags having been obtained in this district. Among these is a species of Ogygia† very like O. scutatrix (figured at p. 53), Trinucleus Gibbsii, and another species; together with Agnostus pisiformis, so abundant in North Wales. Again, there is the same passage upwards into black schists, with trilobites and graptolites, as at Abereiddy Bay, where the planes of slaty cleavage, as represented by the dark tint in the following woodcut, taken from the 'Silurian System,' coincide with the layers or beds containing the fossils.

This Graptolite schist is chiefly characterized by the Didymograpsus Murchisonii, Beck (Pl. I. f. 1), and Calymene duplicata (Asaphus, Sil. Syst.), Pl. III. f. 6.

LOWER SILURIAN ROCKS IN ABEREIDDY BAY.
(From Sil. Syst. p. 400.)

Coincidence of Slaty Cleavage and Bedding.

To the south of this locality all the Silurian rocks are much obscured, the surface being to a great extent occupied by Old Red Sandstone, Carboniferous Limestone, and Culm (see Map).

In South Pembroke, the upper and chief portion of the Llandeilo deposit is alone exposed in the cliffs at Musclewick Bay, where it contains the Asaphus tyrannus and Trinuclei. The black schists of this age are there insulated by a powerful dislocation, which, on their northern side, has placed them abruptly in contact with the Old Red Sandstone; whilst towards Marloes Bay, or southwards, where younger Silurian rocks form

* Sil. Syst. p. 399.

† Ogygia peltata, Salter.

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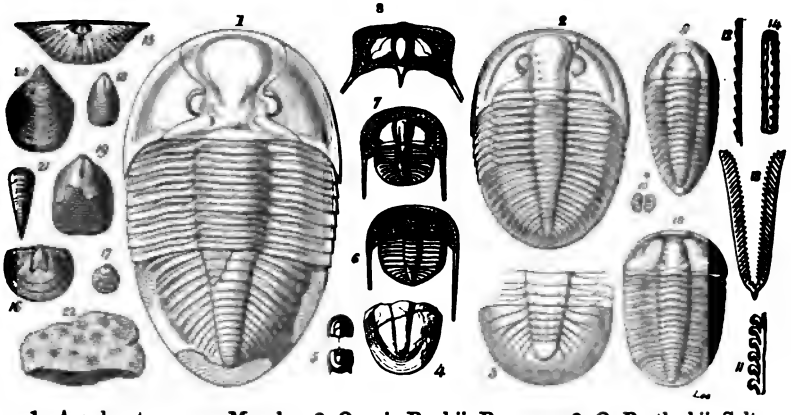
the cliffs, the relations are obscured by a protrusion and overflow of igneous rock, chiefly greenstone†, as in this diagram.

LLANDEILO SCHISTS IN MUSCLEWICK BAY.
(From Sil. Syst. pl. 35. f. 11.)

o. Old Red Sandstone. *b*. Llandeilo Schists. * Eruptive Rocks.

In quitting the dislocated west coast of Pembrokeshire, and advancing from Haverfordwest to the borders of Carmarthenshire, the geologist perceives, that the upper member of the Llandeilo formation puts on a much more calcareous structure. The schists and dark roofing slates of the Precelly Hills have graduated into calcareous flags, which at Llandewi Felfry and Lampeter Felfry become thick argillaceous subcrystalline dark grey rocks, traversed by veins

FOSSILS (10). CHARACTERISTIC FOSSILS OF THE LLANDEILO FLAGS.



1. Asaphus tyrannus, Murch. 2. Ogygia Buchii, Brongn. 3. O. Portlockii, Salter. 4. Stygina (Ogygia) Murchisoniæ, Murch. 5. Agnostus Maccoyii, Salter. 6. Trinucleus fimbriatus, Murch. 7. T. Lloydii, id. 8. T. concentricus, var. *δ*. 9. Calymene brevicapitata, Portl. 10. C. duplicata, Murch. 10*. Beyrichia complicata, Salter. 11. Graptolithus lobiferus, M'Coy. 12. G. tenuis, Portl. 13. Didymograpsus Murchisonii, Beck. 14. Diplograpsus teretiusculus, His. 15. Orthis alata, Sow. 16. O. striatula, Emmons. 17. Siphonotreta micula, M'Coy. 18. Lingula attenuata, Sow. 19. L. granulata, Phill. 20. L. Ramsayi, Salter. 21. Theca reversa, id. 22. Nebulipora favulosa, Phill.

of white calc spar, and constituting fine masses of limestone. These beds are largely worked for lime, and are, as far as I know, the only Lower Silurian rocks in Wales now used for such a purpose. The

† See Map. This coast and the dislocations of the strata will be subsequently described.

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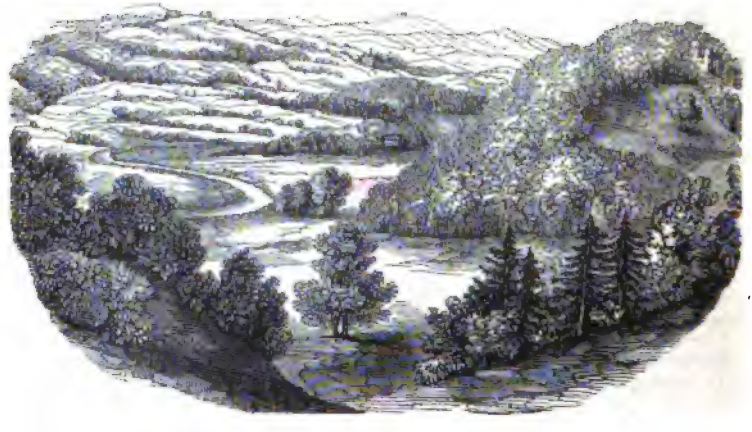
student will have learnt from the previous pages, that throughout all the masses underlying the Llandeilo formation there is little calcareous matter, and an accompanying deficiency of shelly animal remains. In these Llandeilo rocks, however, the original conditions having undergone a considerable change, many more fossils occur. The relations of the strata are here given.

SECTION AT LLANDEWI FELFRY, PEMBROKESHIRE.

b. Llandeilo schists, and b^2 limestones. *c*. Caradoc or Bala beds.

Underlaid by a considerable thickness of black schist (*b*), and surmounted by other strata (*c*), which contain, as will presently be shown, a different group of organic remains belonging to the Caradoc or Bala formation, the massive limestones (b^2) of this section are charged with the Ogygia, Asaphus, Calymene, Trinucleus, and the Lingula attenuata and L. granulata, above figured, together with Leptæna sericea, Orthis striatula, and the well-known chain-coral, Halysites catenulatus,—a fossil which also pervades all the superjacent Silurian limestones of Caradoc, Wenlock, or Ludlow age. When the limestone thins out, its position is some-



VIEW FROM DYNEVOR PARK, LLANDEILO, LOOKING TO THE HILLS ABOVE GOLDEN GROVE. (From Sil. Syst. p. 347.)

times marked by lines of calcareous concretions, in other places by fossils only. At and near the town of Llandeilo, the chief

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member of the formation consists of calcareous flagstones, in part true limestones, which abound with the above-mentioned characteristic fossils. Extending northwards to Llangadock and southwards to Carmarthen, the Llandeilo flagstones rise in the form of a broken, elliptical mass from beneath overlying strata on both banks of the Towy, thus marking an extensive line of excavation in which that river flows.

The preceding sketch conveys a general idea of the outline of the country in which most of the Silurian rocks, from the Llandeilo in the foreground to the overlying formations, are exhibited. The calcareous flagstones are seen here on both banks of the river, and the overlying formations in the distance. The foreground is the beautiful undulating park of Lord Dynevor, and the chief mansion beyond the valley is Golden Grove, one of the seats of Earl Cawdor. The distant hills are composed of Old Red Sandstone and the lower members of the Carboniferous System.

This succession will be better understood by inspecting the annexed diagram, taken from one of the large horizontal sections of the Government Surveyors, which is quite in accordance with my oldest published sections across the same tract.

SECTION NEAR LLANDEILO. FROM THE LOWER SILURIAN TO THE EDGE OF THE GREAT SOUTH-WELSH COAL-FIELD.

(In this diagram the spectator is supposed to be placed a little south of Llandeilo, looking north-east, or up the Vale of the Towy. Hence the points of the compass are reversed in reference to the following diagram, p. 58.)

b. Llandeilo flags and limestone. *b′*. Llandeilo sandstone, &c. *d*, *e*. Upper Silurian rocks. *f*. Old red sandstone. *g*. Carboniferous limestone. *h*. Millstone grit.

Recently, however, the construction of a railroad from Llanelly by Llandeilo to Llandovery has laid open masses of sandstone and schists beneath the calcareous flagstones. This section, as exhibited near Pont Ladies, on the left bank of the Towy, deserves notice. There the following beds dip to the E. by S. at an angle of 75°.

1st. Dark schists with sandstone courses which graduate upwards into thin schists with nodules. 2nd. Strong bands of hard siliceous light-coloured grits, alternating with thin courses of black shale or schist,

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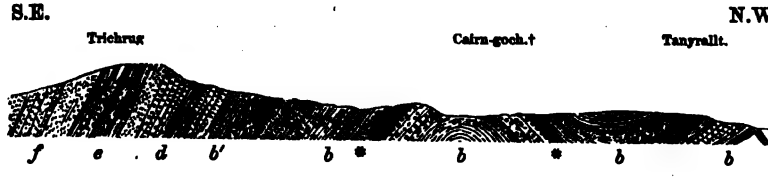
which, predominating upwards, contain some remains of trilobites. 3rd. Calcareous grits and pebble beds, with remains of Orthidæ and corals, followed by schists in which the Asaphus tyrannus is conspicuous, the group being covered by hard siliceous grits, the masses of which are full of annelide trails and of concretions. 4th. Calcareous, dark-coloured, finely laminated flagstones and schists, similar to those at Llandeilo and in Dynevor Park, and containing, together with Asaphus tyrannus, the following:—Calymene brevicapitata, Trinucleus Lloydii, Leptæna sericea, Orthis calligramma, &c.

The same arched arrangement of the strata is traceable to Llangadock, where a dome of grits and sandstone, like those of Pont Ladies, emerges from beneath the superior strata, as represented in this diagram.

SECTION NEAR LLANGADOCK. FROM THE LOWER SILURIAN TO THE OLD RED SANDSTONE.

(The spectator is looking to the south-west.)



b. Undulations of Llandeilo schists, flags, and limestone, with interstratified trap*. *b'*. Llandeilo sandstones, &c. *d*, *e*. Upper Silurian. *f*. Old red sandstone.

Of like age also are the grits and pebbly beds of Mount Pleasant and other places opposite Carmarthen, from whence the fossils, Orthis alata, Bellerophon (Euomphalus) perturbatus, Nucula lævis, and Stygina (Ogygia) Murchisoniæ, were obtained during my early labours (1833–4‡).

Whilst such are the chief features of the Llandeilo rocks in Carmarthenshire, it is essential to remark, that certain sandy beds on the left bank of the Towy (*b'*), ranging by Cairn-goch, which were formerly considered to be Caradoc Sandstone (see Sil. Syst. p. 354), are now known by their imbedded remains to belong to the Llandeilo formation. Along this frontier therefore, notwithstanding an apparent conformity (for the old sections published in the 'Silu-

† Cairn-goch is a remarkable and rather large British fort, in which the defenders have availed themselves of the smooth faces of a steep anticlinal of these grits, as walls of defence, the ends of the entrenchment being blocked up by loose fragments of the stone.

‡ See Sil. Syst. p. 358, and pl. 25.

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rian System' scarcely differ from those of the Government Surveyors), there is, it appears, a hiatus, as determined by the subsequent labours of Ramsay, Aveline, and Salter. There, on the left bank of the Towy, the true Caradoc group (*c*) is omitted, and the Upper Silurian rocks, with a feeble trace of a sandy rock containing Pentamerus oblongus, at once overlap the Llandeilo formation. This arrangement, by which the Caradoc formation is excluded, extends all along the left bank of the Towy from the environs of Carmarthen, by Llandeilo, and is prolonged far to the N.E.

On the other hand, a natural exhibition of the Caradoc or Bala rocks is seen on the opposite bank of the river, where an unbroken ascending series is exhibited, in which both the Llandeilo and Caradoc formations are exposed in conformable apposition. To the north of Llandeilo, the calcareous trilobite flags folding over to the N.N.W., are at once surmounted by a great thickness of fossiliferous schists and sandstones with some calcareous courses, which clearly represent the original Caradoc Shelly Sandstones, to be described in the next Chapter †.

In short, the Llandeilo flags and schists of Pembrokeshire and Carmarthenshire, charged with the same characteristic trilobites and other fossils, emerge everywhere from beneath overlying deposits, often of a more arenaceous type, which are of the age of the Caradoc or Bala formation. In Carmarthenshire, the Llandeilo flags are associated, as elsewhere, with igneous rocks, both stratified and eruptive, though not on the same scale, or of that clear and demonstrative character which is exhibited in the tract of Shelve in Shropshire, and in the intermediate district between Builth and Llandegly. By reference to the Map it will, indeed, be seen, that it is just where such igneous rocks abound, as marked by bright red colour (*), whether in Shropshire or in Wales, that the Llandeilo formation (2^b) rises prominently to the surface, through the surrounding deposits.

† To the north and west of the Llandeilo district, and all along the western frontier of the Builth country, the boundary-line of my old map of the Silurian Region, which separated the Silurian rocks from the so-called Cambrian of that day, was purely arbitrary. It is merely to be regarded as a demarcation between rocks with which I was acquainted, and a vast *slaty* region which I had not examined, and with whose order and fossil contents I was unacquainted; though I believed it to be of older date. Hence I mapped it as Cambrian, as well as all the region to the west and north, now known to be younger than Llandeilo Flags.

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Thus, in proceeding from the Llandeilo tract to the north-east, we first meet with decisive eruptive masses of porphyry and other rocks at and near the Wells of Llanwrtyd in Brecknockshire, and there black schists and flags of this age, often highly altered, again prevail. With the loss of calcareous matter, however, the schists of Llanwrtyd no longer exhibit the characteristic trilobites and shells of the formation, though they contain some graptolites. There the beds are so slaty and crystalline, that the highly inclined cleavage of the slates, as represented in the foreground of the following sketch, is the only feature visible to the unpractised eye; the real strata undulating or dipping at a much less angle, as represented in the sloping bank on the left of the foreground of this drawing.

LLANWRTYD WELLS.

S.E. (From Sil. Syst. p. 336. See also woodcut, Sil. Syst. p. 343.) N.W.

Lower Silurian slaty rocks.

View in a combe below the Baths of Llanwrtyd. (From a drawing by Mrs. Traherne.)

When viewed, however, on the grand scale, there is no district more explanatory of the general succession than this very tract between Llandovery and Builth, of which the above vignette represents a part. There, if the spectator stands on the summit of the mountain of Esgair Davydd, above the Baths of Llanwrtyd, he overlooks a wide area to the south-east, and has beneath his feet, and for a certain distance before him, a mass of the lower slaty rocks now under consideration; whilst in the dull round hills of the middle ground are spread out the Upper Silurians of the Mynydd Epynt and

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VIEW FROM THE SLATY LOWER SILURIAN ROCKS (*a*) NEAR LLANWRTYD, BRECON, OVERLOOKING ROUNDED HILLS (*b*) OF UPPER SILURIAN, WITH MOUNTAINS OF OLD RED SANDSTONE IN THE DISTANCE, THE LATTER BEING DEFINED BY THE UNTINTED OUTLINE.
(From a coloured drawing, Sil. Syst. p. 346.)

Mynydd Bwlch-y-Groes, as in this diagram. In the background, the Old Red Sandstone is seen rising to the Black Mountain of Hereford, and thence into the Fans of Brecon and Carmarthen, the highest mountains in South Wales.

In the hilly district extending from Builth on the Wye to Llandrindod and Llandegly (see Map), the Llandeilo formation again rises to the surface in the form of a rugged ellipsoidal mass, throughout which igneous rocks, both stratified and eruptive, prevail. In the sequel it will be shown how that tract, as well as the district of Shelve (both originally described in the 'Silurian System'), present, to the geologist, physical features and rocks similar to those of the grander mountains of North Wales. The environs of Builth and Llandrindod afforded, indeed, a very large portion of the fossils originally published as typical of the Llandeilo rocks*.

Whether collected at Wellfield and other places near Builth, or in the flagstones north of the Carneddau Hills, the Ogygia Buchii, Ampyx nudus, Agnostus Maccoyii, and the Lingula attenuata are found in abundance, with beds full of Orthis calligramma and other characteristic shells.

Near Builth, however, as in the west of Shropshire, there is no equivalent whatever of the Caradoc or Bala formation. This omission is explained in these two

* So much importance was attached to the locality of Builth, that in an early memoir (Proc. Geol. Soc. vol. ii. p. 23), I termed the deposit, 'Builth and Llandeilo Flags.'

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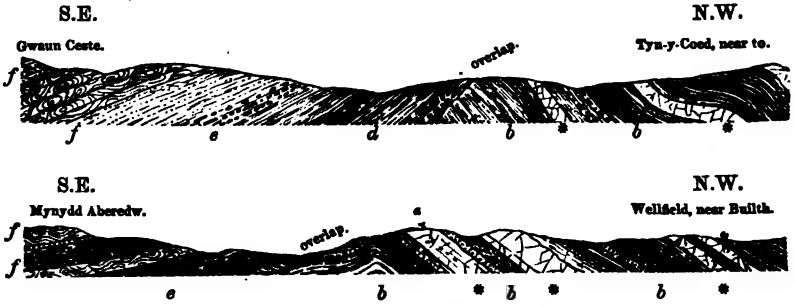
sections, taken from the publications of the Survey, which represent the Upper Silurian, with an occasional thin course of Llandovery rock, reposing upon the edges of the Llandeilo formation.

UNCONFORMABLE RELATIONS OF LLANDEILO FLAGS AND UPPER SILURIAN. NEAR BUILTH.

(Taken from Horizontal Sections of the Government Survey.)

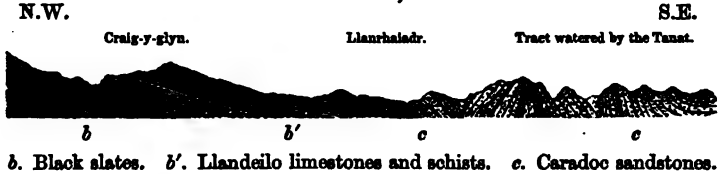


b. Llandeilo formation. *d*. Thin course of Upper Llandovery rocks, the Caradoc or Bala (*c*) being absent. *e*. Wenlock rocks. *f*. Ludlow rocks. (In the lower section the omission is still larger, there being no trace even of the Upper Llandovery rocks.) * Trap rocks.

Again, when we travel westwards from the typical tract in Shropshire (see Map), where, as already shown, the Llandeilo formation reposes clearly on the Stiper Stones, we lose all traces of it until we reach the eastern flank of the Berwyn Mountains; the intermediate country being occupied by younger deposits, from the Caradoc or Bala formation upwards,—thus clearly indicating that various parts of these regions have been subjected to powerful local oscillations, leaving here and there only the unbroken segments of the whole series of successive deposits, accompanied by the organic remains peculiar to each.

On the other hand, the annexed diagram† represents how the

LLANDEILO AND CARADOC ROCKS, E. FLANK OF BERWYNS.



b. Black slates. *b'*. Llandeilo limestones and schists. *c*. Caradoc sandstones.

Llandeilo formation, consisting of black slates (*b*) in the lower part

† This diagram is like the section in the 'Silurian System,' pl. 32. f. 9.

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and of overlying calcareous flagstones (*b'*, occasionally burnt for lime), occupies the eastern slopes of the Berwyn Mountains, as exposed in the gorge of the rapid river Twrch at and below Craig-y-Glyn, and above the small town of Llanrhaiadr. The masses more or less calcareous have a thickness of 400 or 500 feet, and are laden in their lower part with Asaphus tyrannus, Encrinites, and Corals, and in their higher portion with Trinucleus concentricus (T. Caractaci, Sil. Syst.), Acidaspis, Leptæna sericea, Orthis turgida, &c.

All these strata, perfectly identical through their fossils with those of the Llandeilo formation elsewhere, dip at an angle of about 25° to the S.E., and pass with perfect uniformity under that series of shelly sandstones which undulate over this picturesque northern portion of Montgomeryshire. The latter were identified during my early researches with the mass of the Caradoc Sandstones.

This view has been confirmed; the Bala limestone and associated beds being now further known to be identical with these overlying shelly sandstones of the vales of Meifod and of the Tanat*.

The distinctions of this overlying or Caradoc formation, both lithological and zoological, will be described in the next Chapter. It should here, however, be stated, that on the flanks of the Berwyn Mountains, as in the valleys of the rivers Ffyrnwy and Tanat, the Lower Silurian rocks have been affected by a transverse slaty cleavage, from which they are usually exempt in the typical tracts wherein the Silurian classification was established.

In thus collating all the results of those explorations of Wales, which commenced with the labours of Sedgwick and myself, and have been since extensively and accurately developed by the Government Geological Surveyors, we learn how local elevations have, here and there only, raised to the surface the strata which connect the broken succession of former life. When the Upper Silurian Rocks shall have been described, the omissions of certain deposits in some parts and their attenuation in others will be placed in tabular apposition to the complete series.

Having spoken of the tracts where the Llandeilo schists and flags are clearly recognizable through their position and organic remains, it is not pretended that a line can everywhere be precisely drawn upon

* Sil. Syst. p. 306 *et seq.*

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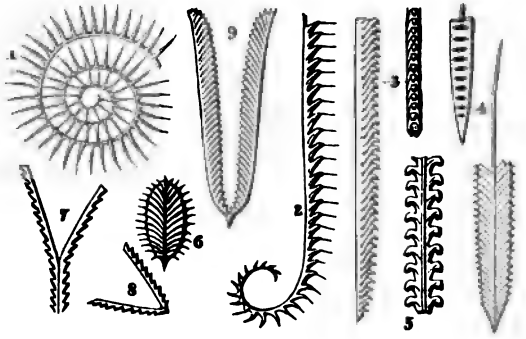
a map, between them and the Caradoc formation; and thus on the accompanying Map the tint 2^b is shaded off into the colour of 2^c. In all such cases of junction and passage, the general term of Lower Silurian can, it is obvious, be alone with safety applied.

In terminating this sketch of the Llandeilo formation, a few words may be offered on the fossils called Graptolites, already partially adverted to, and which, wherever they are found, clearly mark the rock to be Silurian. They occur, indeed, in North and South America, Britain, Scandinavia, Germany, Russia, France, and Spain. Abounding in the lowest strata of the Llandeilo formation which graduate downwards into the Stiper Stone flags, these graptolites are specially abundant in the very tract of Shropshire (Stiper Stones to Shelve) on which such stress has been laid as affording the best illustration of a large mass of the inferior strata. They prevail, in

FOSSILS (11). LOWER SILURIAN GRAPTOLITES.



1. Rastrites* peregrinus, Barr. 2. Graptolites Sedgwickii, Portl. 3. G. priodon, Bronn. (G. Ludensis, Sil. Syst.) 4. Diplograpsus pristis, His. 5. D. nodosus, Harkness. 6. D. folium, Hising. 7. D. ramosus, Hall. 8. Didymograpsus sextans, Hall. 9. D. Murchisonii, Beck.

fact, throughout the Silurian system wherever the nature of the sediment has been favourable to their existence, *i.e.* in purely schistose and argillaceous strata, or the finely levigated muddy bottoms of the primeval seas. They are supposed by many naturalists to have been zoophytes, nearly allied to the living Virgularia, a creature known only in the deeper water. Others rather consider these extinct

* See Geinitz (Verstein. Grauw.-Formt.), who, for the sake of uniformity, groups all the Graptolites with a single row of teeth (Graptolithus, Rastrites, &c.), under the name *Monograpsus*. Recently, some forms have been discovered in Canada much more complex in structure than any here figured.

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forms to belong to Sertularian Zoophytes, or even to Bryozoa*. Be this as it may, the geologist has observed that they are found *exclusively* in the Silurian system of life. The whole group of these little serrated fossils has been called Graptolithina, and has been divided into about four genera, as represented in the foregoing woodcut.

One of these genera, the Graptolites, Foss. 11. f. 2, 3, has teeth or cells on one side only. A second, the Diplograpsus, M'Coy, f. 4, 5, 6, 7, is distinguished by having a double series of lateral teeth. A third, Rastrites, Barrande, f. 1, has teeth placed like the first-mentioned, but not so crowded together. There are also others, which have twin branches, f. 8, 9, and for which the name of Didymograpsus has been proposed; one of these, the D. Murchisonii, f. 9, is the most characteristic fossil in the black Llandeilo flags of Wales: it has also been found on the continent (Cladograpsus of Geinitz). Some of these forms, as published in the 'Silurian System,' are figured in Pl. 1. and Pl. 12.

The Diplograpsi, or doubly serrated forms, are chiefly characteristic of the Lower Silurian rocks; D. pristis, Foss. 11. f. 4, and D. foliaceus, Pl. I. f. 2, being ordinary forms. The one-sided species extend from the Lower to the Upper Silurian.

We now know, that one of the species of this group, the G. priodon, Bronn, or G. Ludensis, Sil. Syst., ranges from the Llandeilo formation to the Ludlow rocks inclusive, having been named Ludensis from its occurrence in the uppermost member of the Silurian series. In no Paleozoic rock younger than the Silurian is, I repeat, the true graptolite known. Hence, as types, they are most important to the practical geologist, who, in exploring many strata of this age in Cumberland, the southern counties of Scotland, Ireland, Central Germany†, &c., meets with scarcely any other fossils. In Sweden, indeed, graptolites and fucoids so abound, as to have given a highly bituminous character to the lower strata, which, being also largely impregnated with iron pyrites, have afforded so much alum as to have procured for them the name of Alum slates.

* There seems to be strong reason for entertaining this latter view of their affinities; see also above, p. 47.

† Dr. Beck of Copenhagen described the few species of Graptolites in the 'Sil. Syst.' M. Barrande has since published a most elaborate and valuable treatise on the Graptolites of his Silurian Basin in Bohemia. Dr. Geinitz has systematized all the known forms of Graptolites in a work, illustrated by clear and beautiful drawings, entitled 'Die Versteinerungen der Grauwacken-Formation in Sachsen.' Leipsic, 1852.

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Whilst, however, the mere presence of a graptolite will at once decide that the enclosing rock is Silurian*, it is only by finding the genera of these animals which display a double set of serratures, as in several of the above figures, that, in the absence of signs of the order of superposition, the field observer may presume he is examining the lower division of the system.

* It will be seen in the sequel that these true Silurian types occur in Norway and Sweden in strata of the same age as the Lingula Flags and Stiper Stones of Britain or the bottom beds of the series.

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CHAPTER IV.

LOWER SILURIAN ROCKS—(*continued*).

THE CARADOC FORMATION, OR SHELLY SANDSTONES OF CAER CARADOC.—GENERAL CHARACTER AND ORDER IN THE TYPICAL SILURIAN TRACT OF SHROPSHIRE.—CHIEF ORGANIC REMAINS AS DISTINGUISHED FROM THOSE OF THE LLANDEILO FORMATION.—GREAT MASSES OF THE SLATY ROCKS OF WALES, INCLUDING THOSE OF BALA, SHOWN TO BE THE EQUIVALENTS OF THE CARADOC OF SHROPSHIRE.—IGNEOUS ROCKS, CONTEMPORANEOUS AND ERUPTIVE, OF LOWER SILURIAN AGE.

THAT certain sandstones and shales with occasional calcareous or shelly courses overlie the schistose rocks of the Llandeilo formation in Wales, has already been adverted to*. But before we pursue their clear and consecutive relations, let us view those masses of the same age in Shropshire, which, with their fossils, were originally described as a formation younger than the Llandeilo Flags, and as underlying all the Upper Silurian rocks. For, this Caradoc formation and its characteristic fossils having been described and named many years before its equivalents in Wales were brought into comparison or their fossils examined, the account of the original type naturally precedes any other description of strata subsequently ascertained to be of the same age.

In Shropshire, the Caradoc Sandstone, so named from the ridge on the flanks of which it is well exposed, is cut off, as formerly shown, from the next inferior deposits, or Llandeilo Flags, by powerful dislocations and by the intervention of the Longmynd (see Map). Whilst a perfectly symmetrical ascending order occurs, as already stated, on the west flank of the Longmynd, from the Cambrian into the Lower Silurian rocks, in vain do we look on the eastern side of that mountain for any representative of the Stiper Stones and the great Llandeilo formation of the Shelve and Corndon tract (pp. 38, 39). The steep slopes of the Longmynd which overhang the valley of Stretton exhibit, as already shown (p. 24), the escarpment or lowest beds of that enormous mass of ancient sedimentary rocks. (See Map.)

* See also general section beneath Map, and local sections (pp. 57, 62).

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Immediately to the east of that valley is seen the line of a powerful fault, the vertical dimensions of which have been estimated at not less than 2000 feet (by Professor Ramsay), the place of the intervening strata being taken by igneous rocks. The latter, having been erupted at a period long after the formation of the original sediments, have altered the schists into hard clay slates, and the sandstones into quartz rock. These igneous and altered rocks constitute, indeed, some of the highest points of the Caradoc Hills. The annexed view, taken from the eastern flank of the Longmynd by Mrs.

THE CARADOC RANGE.

Stackhouse Acton, will convey to the reader a good idea of the outline of this eruptive ridge, which trends from the hill of Ragleath on the S.S.W., to the Lawley on the N.N.W.; the intermediate hills being those of Hazlar and Helmeth; whilst the chief and loftiest central mass, or that of Caer Caradoc, gives its name to the whole range. No stronger proof of the great break which here occurs can be given than that on the western flanks of the eruptive ridge, or between the Caradoc formation and the Longmynd, a large mass of Upper Silurian (Wenlock) limestone has been thrown into a vertical and insulated position at Botville*: it is thus wedged in between the Caradoc Sandstone and the Longmynd rocks—the base of the whole sedimentary series (see the following woodcut).

* See Sil. Syst. p. 231, and pl. 31. f. 4.

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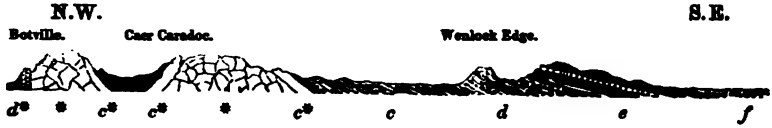
Striking masses of the altered sandstone are exposed at Cardington, Hope Bowdler, and other places, and this small general section explains the facts.

RELATIONS OF CARADOC SANDSTONE TO THE UPPER SILURIAN ROCKS IN SHROPSHIRE.



* Eruptive rocks. c^*. Caradoc sandstone altered by eruptive rocks. *c*. Caradoc Formation, surmounted by Pentamerus limestone. *d*. Wenlock rocks. *e*. Ludlow rocks. *f*. Old red sandstone. d^*. Vertical Wenlock limestone (Botville).

But, notwithstanding all the disorder and change resulting both from a great fault upon the N.W. and the protrusion of the igneous rocks of the ridge, the various overlying strata which compose the great body of the Caradoc formation are observed to succeed each other with perfect regularity.

Proceeding from the eastern flank of the eruptive masses, and receding from the altered strata which adhere to the sides of the syenitic greenstone, felstone, and other rocks† forming the nucleus of the ridge, the fullest and clearest exhibitions of the overlying 'Shelly Sandstones' under review are to be seen in any transverse section which the explorer may examine as he proceeds towards the younger strata of the Wenlock Edge.

The accompanying sketch (p. 70), reduced from a coloured lithograph in the original work (Sil. Syst. p. 217), will explain better than pages of description how these stratified deposits constitute the well-defined hills to the east of the igneous range.

In the foreground is the steep flank of the Caer Caradoc (*), and beyond it to the left is the Lawley, or north-eastern end of the ridge: the Wrekin, another igneous outbreak through the Silurian strata, being on a different parallel, is seen in the central distance. The remainder of this view exhibits, even in the outline of the ground, a true indication of the succession of the various formations as first defined by myself in the years 1832–3.

† The details of the mineral structure of the eruptive rocks of the Caradoc range are given in the 'Silurian System.' The predominant rock is hard pinkish-coloured felspar or felstone, slightly porphyritic, from which there are passages into varieties of hornstone, syenite, and greenstone; globular concretions with actinolite are not unfrequent, and coatings of quartz rock or altered sandstone are common (see Aikin, Geol. Trans. i. p. 210; and Sil. Syst. p. 226).

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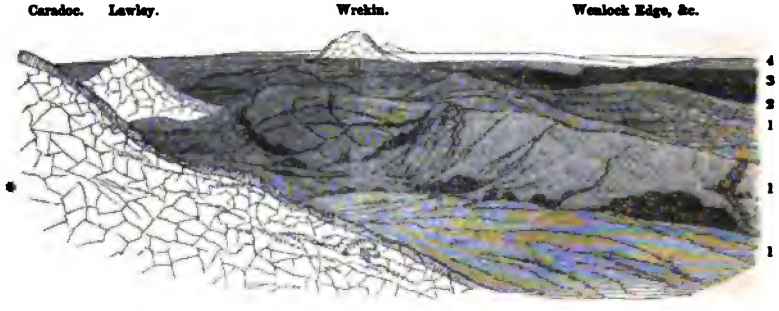
The slopes marked 1, 1, 1, constitute the chief masses of the Caradoc or shelly sandstone, exposed in a thickness of several thousand feet.

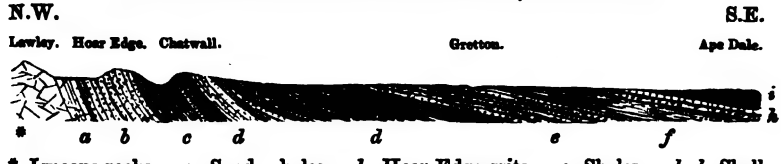


VIEW FROM THE EAST SIDE OF CARE CARADOC (Sil. Syst. p. 216).

The thin zone, to which the figure 2 is affixed, is a band formerly connected with the Caradoc strata, but whose intermediate relation to the rocks below and above it will be explained in the next Chapter; 3 stands for the Wenlock shale and limestone displayed in the Wenlock Edge; whilst 4 represents a part of the distant overlying Ludlow rocks. The spectator has thus before him at one glance, a large portion of the Lower Silurian rocks, a thin intermediate zone, as well as the overlying Upper Silurian; and all within the range of five miles from N.W. to S.E. The remote flat country to the left, or to the north-east and north, is composed of Carboniferous rocks and New Red Sandstone.

The real order and thickness of the strata exhibited in the sketch can, however, be best understood by presenting to the reader a detailed geological section across the same typical district.

RELATIONS OF THE CARADOC FORMATION, SHROPSHIRE.



* Igneous rocks. *a*. Sandy shales. *b*. Hoar Edge grits. *c*. Shales. *d*, *d*. Shelly sandstones. *e*. Cheney Longville flags. *f*. Trinucleus shales. *h*. Pentamerus limestone. *i*. Wenlock shale.

(From the large horizontal section of the Government Survey made by Mr. Aveline.)

The strata which compose the great mass of the formation to

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which the name of Caradoc Sandstone was assigned succeed each other in the following order. The lowest beds, which are clearly exposed, dipping away from the intrusive rock (*), are sandy shales (*a*), with some courses of shelly sandstone, in part a bastard-limestone, which rise to the surface in the hilly grounds of Acton Burnell, and are thence prolonged by Frodesley to the Lawley, or the terminating hill of the eruptive ridge. From that point to the valley (Ape Dale) under Wenlock Edge the succession of the strata is clear. The lowest beds, or sandy shales (*a*), have been hollowed out into a valley. The next overlying strata, as seen in the sketch and section, consist of light-coloured, yellowish, siliceous sandstones, in part coarse grits (*b* in the Section), which occupy the sharp ridge called the Hoar Edge, along which they are extensively quarried, and are seen to plunge at high angles to the south-east.

Another valley succeeds, which has been excavated in softer and more shaly beds (*c*). These, resting upon the siliceous rocks of the Hoar Edge, dip under a second sandstone ridge (*d*), which extends by Chatwall and Enchmarsh to Soudley. These last-mentioned sandstones (*d*) contain layers of fossil shells, which occasionally so abound as to convert some of the beds into impure limestones. Their prevailing colour is a dirty dull or purplish red, but they are occasionally variegated with brownish, yellowish, and greenish tints. In some quarries not far from Acton Scott they are striped in ribbon fashion with dark red and light green layers; and, being here and there also spotted, they thus resemble both the Old and New Red Sandstones of long-subsequent eras. Along the ridge of Enchmarsh, or at Soudley, they are extensively quarried for use, and are as easily worked as many freestones of the younger formations, reckoning from the carboniferous sandstones upwards. They are therefore very peculiar, as long ago remarked†, in being the oldest strata of Britain which present such a comparatively recent lithological appearance—one entirely differing from anything to which the word 'grauwacke' had ever been applied by geologists. And yet, notwithstanding their soft and sectile character, these Caradoc sandstones are laden with a profusion of fossils of the same species as occur in the hard, slaty, argillaceous rocks of large regions of Wales, with which they were truly identified in a few tracts, at the period of the publication

† Sil. Syst. pp. 216–222.

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of the 'Silurian System*.' In short, these shelly sandstones, so near to the Wenlock Edge, and so clearly overlaid by a full Upper Silurian series, form essentially a vast portion of the same great Lower Silurian division to which the preceding chapters have been devoted, and whose strata in a more crystalline and slaty state are spread over such large tracts of Wales. The manner whereby this result has been fully worked out, amidst the difficulties of so complicated a region, is one of the greatest triumphs of my successors in that diversified Silurian field.

A great thickness of these shelly sandstones is exposed in the sides of the steep lanes leading down from the ridge of Enchmarsh and Chatwall to Cardington, near to the last of which places their uppermost or flag-like finely laminated courses (*e*) have recently been laid open at Gretton†. There, a vast abundance of characteristic fossils have been obtained; nearly all of them being forms equally well known in the Bala rocks of North Wales. These beds (*e*) were formerly designated Cheney Longville Flags, from their being well exposed at the hamlet of that name on the right bank of the river Onny. They graduate upwards into earthy beds or shales (*f*), which in this district are laden with the well-known trilobite *Trinucleus Caractaci*‡. This beautiful fossil is found from the base to the summit of the formation, and was named by me after the old British King and the adjacent ridge that still bears his name. Other sections across the strata enumerated may be observed in other traverses of the same district. The clearest of them, as exposed upon the banks of the Onny, between Horderley on the north-west, and Wistanstow on the south-east, was given in detail in my earliest work. It is enough to recapitulate, that the lower of the shelly sandstone masses to which we have been calling attention, exhibiting courses of calcareous grit ranging from Horderley to Corton, were described as containing the Orthis flabellulum, O. vespertilio, O. unguis, Stro-

* The sandstones, &c. of Welsh Pool, and of the valleys of the Tanat and Ffyrnwy, were, together with the Meifod rocks, unhesitatingly identified with these Caradoc Shelly Sandstones (Sil. Syst. pp. 302–307, and pl. 32. f. 9).

† This quarry was not opened when I prepared the 'Silurian System,' and was about to be filled in when I visited the tract in 1856.

‡ This fossil is now termed Trinucleus concentricus; it having been since ascertained, though unknown to me when I first proposed the above name, that Mr. Eaton of the United States had described it as T. concentricus, shortly before I published my work. The Trin. tessellatus of Green is the same species; and it has also received other names from paleontologists.

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phomena expansa, Crinoids, and Trilobites; whilst the superior beds were said to abound in different Orthidæ, particularly O. Actoniæ and O. (Strophomena) grandis, and Trinucleus Caractaci. The Soudley and Enchmarsh beds of freestone were shown to range to the Long Lane and other quarries of sandstones with calcareous courses.

The upper beds, which at Cheney Longville pass up into sandy shale, were described as very fine-grained, slightly micaceous sandstone, of green and dingy olive-green colours, in beds of one to six inches thick, and as enclosing here and there shelly calcareous courses, or impure limestones. Looking to the composition of these beds, and others lower in the series and nearer to the eruptive ridge, I inferred that some of them must have been deposited in a sea rendered turbid by volcanic action, so as to form strata which, if fossils were excluded, mineralogists would term sandy clay-stone. I then also stated that they constituted the last lithological term in that series of volcanic rocks of which a description will be given at the end of this Chapter.

The remains of fossils often so abound as to render some of the courses shelly limestones; these have occasionally been burnt for use, and are known to the workmen of the neighbourhood as "Jacob's Stones." When the calcareous matter is diffused in small particles through the mass, the rock becomes a hard calcareous grit, usually of a whitish drab colour, breaking under the hammer with a conchoidal and lustrous fracture. On the banks of the Onny, between Horderley and Wistanstow, there is also a band of impure limestone, formed however chiefly of quartzose pebbles cemented by lime.

The recent cuttings along the Hereford and Shrewsbury railroad have laid open hillocks of the formation between Church Stretton and Marsh-Brook. These rocks consist of purple and red earthy sandstones, in parts micaceous, with partings of green earth, some courses of the shelly beds or "Jacob's Stones," and brown calciferous grits. Near Church Stretton the rock is earthy and incoherent, and in it is Diplograpsus pristis, Foss. 11. f. 4, a common Lower Silurian graptolite, which occurs in the Bala schists in many parts of Wales. This variety of the sandstone is concretionary, exfoliates into balls on weathering, and is full of

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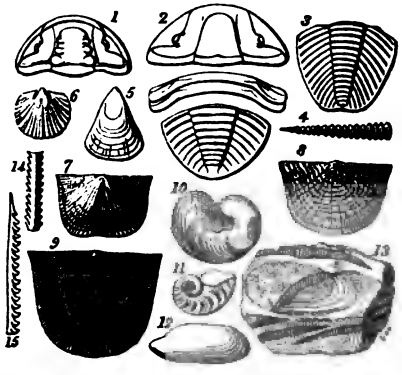
irregular joints, the surfaces of which are coated with a film of the indigo-coloured oxide of iron so common in the Ludlow rocks.

Some of the most characteristic fossils of the formation are given in this woodcut.

CARADOC FOSSILS (12).



1. Calymene Blumenbachii. 2. Homalonotus bisulcatus, Salter. 3. Phacops truncatocaudatus, Portl. 4. Tentaculites anglicus, Salter. 5. Lingula crumena, Phill.* 6. Orthis testudinaria, Dalm. 7. O. vespertilio. 8. Strophomena tenuistriata. 9. S. grandis. 10. Bellerophon bilobatus. 11. B. nodosus, Salter. 12. Orthonota nasuta, Conrad. 13. Nebulipora lens, M'Coy. 14. Diplograpsus pristis, His. 15. Graptolites priodon.

In addition to the above, the following characteristic fossils are figured in Plates 5 to 7, or in the woodcuts of the next chapter:—Orthis elegantula; O. flabellulum; O. Actoniæ; O. calligramma (virgata, Sil. Syst.); Strophomena expansa; S. spiriferoides, M'Coy; Leptæna sericea; Modiolopsis orbicularis (Avicula, Sil. Syst.); M. modiolaris, Conrad; M. obliqua; Bellerophon acutus; Phacops conophthalmus, Eichw. The species with no author's name attached are published in the 'Silurian System.'

Other fossils which abound are represented in Plates 5 to 7 of this work, and are exact reprints of the figures published as original Caradoc types from this district. Among them, the geologist who may have explored North Wales will perceive the fossils which occur in many parts of that region, including the casts of Brachiopods which he may have collected from the summit and slopes of Snowdon.

In the lists of fossils given in the memoir by Salter and Aveline on the Caradoc Sandstone (Journ. Geol. Soc. Lond. vol. x. p. 62), we find that the Trinucleus Caractaci (Sil. Syst.) ranges from the lowest to the highest beds. The Hoar Edge grits contain Phacops apiculatus, Salter, Homalonotus rudis, id., Beyrichia complicata, id., Orthis Actoniæ, O. fla-

* The Lingula crumena, f. 5, has been placed in the above woodcut by mistake; it belongs to the overlying Llandovery rocks, into which the Caradoc passes upwards in S. Wales.

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bellulum, O. vespertilio, O. testudinaria, and O. calligramma, most of these being species described in the 'Silurian System' as typical of the Caradoc formation. With them, however, is associated the Calymene Blumenbachii, so common in the Upper Silurian division.

Two trilobites, highly characteristic of this zone, whether in Shropshire or N. and S. Wales, which were omitted in my former work, are given in this woodcut. The Trinucleus seticornis, Hisinger (f. 1, 2), is found wherever the Caradoc rocks take on a calcareous or shaly character. The Phacops apiculatus, Salter (f. 3), on the other hand, was a denizen of sandy submarine ground, and is plentiful in the sandstones of Shropshire and North Wales.

CARADOC TRILOBITES (13).

Ascending to the higher strata through courses of the freestone above noticed, in which some of the same Orthidæ occur with other forms, we reach the thin-bedded Cheney Longville flags of my earlier sections. At one or two localities where this zone appears at the surface, and chiefly at Gretton, the following copious list has been made out, nearly all the species being also known in the Welsh mountains around Bala, or on the summit of Snowdon, &c. Those marked * are most abundant.

Acidaspis Caractaci, n. s.; Calymene Blumenbachii*; Homalonotus bisulcatus*; Phacops truncato-caudatus*; P. conophthalmus*; Lichas laxatus; Illænus; Tentaculites anglicus*; Serpulites; Cornulites serpularius; Orbicula elongata (Portl.); Orthis vespertilio*; O. elegantula*; O. Actoniæ; O. biforata; Strophomena* resembling S. grandis; S. tenuistriata*; S. bipartita*; Leptæna sericea*; L. transversalis*; Modiolopsis orbicularis*; Nucula varicosa*; Murchisonia simplex; Turbo crebristria; Conularia Sowerbyi; Bellerophon bilobatus*; B. acutus*; an Orthoceras; with a profusion of fragments of Encrinites, Bryozoa, and several Corals, of which the Stenopora fibrosa and Nebulipora favulosa (var. lens) are the most frequent.

The uppermost band strictly belonging to this formation has been called the Trinucleus Shales. It is still charged with the prevailing Trinucleus Caractaci (concentricus, Eaton), and the Lower Silurian brachiopod Leptæna sericea, with Orthis elegantula, Nucula, &c.

In working out the classification first propounded in the 'Silurian System,' I also grouped with the Caradoc formation certain beds of pebbly grits and impure earthy limestone, which, overlying the

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great mass of the inferior shelly sandstone of Shropshire, are seen to pass under the Wenlock formation. Whilst in the first edition of this work I pointed out a discovery made since my early survey in regard to the physical relation of these strata to the inferior rocks, I still held to the opinion that they ought rather to be grouped with the Lower than the Upper Silurian rocks, and hence I spoke of them as Upper Caradoc. A re-examination of tracts in South Wales, where these deposits are more fully developed than in Shropshire, has led me to consider them as a formation intermediate between the two great groups of Lower and Upper Silurian, and as connected through their organic remains with both. They will therefore be described in the next Chapter under the name of 'Llandovery Rocks.'

Caradoc or Bala Formation in Wales.—Adopting the belief prevalent among geologists when the Silurian classification was proposed, that the slaty and crystalline rocks of Wales were, as a whole, of older date than the softer mud-stone rocks on the east, the greater part of the former were referred, without proofs of infraposition, to an older class of deposits. That erroneous view was indeed abandoned very shortly after the publication of the 'Silurian System,' or seventeen years ago,—*i.e.* as soon as it was ascertained that the fossils of Snowdon and Bala were identical with those of previously described Silurian rocks.

A careful comparison of the fossils of North and South Wales with those of the Caradoc sandstones of Shropshire, and a reference to certain natural sections, have in fact enabled us to go still farther, and to make a separation between the Llandeilo and Bala formations, which, for want of such detailed acquaintance, was not attempted even when the first edition of this work was published. This distinction is truly of great interest to myself, as it brings out the value of the original classification of the Lower Silurian rocks, which indicated a great inferior schistose group charged with large trilobites (Llandeilo), as followed by more arenaceous strata,—Shelly Sandstones, or the mass of the Caradoc formation.

Looking at the general section under the Map, the reader will at once see how the beds of Llandeilo age are surmounted throughout North Wales by strata of the Caradoc age, and how the last are followed by other formations, of which hereafter. In truth, this

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identification of the Bala fossils with those of the shelly sandstones of Caer Caradoc has removed all difficulty in applying the Silurian succession to great masses of Wales, the rocks of which, being in a crystalline and slaty condition, are very unlike their unaltered equivalents in Shropshire.

It has now transpired, that the physical relations and paleontological distinctions between the Llandeilo Flags on the east flank of the Berwyns (the most westerly point which I formerly examined) and the overlying fossiliferous strata of the tract watered by the Tanat and the Ffyrnwy rivers, as given in the 'Silurian System,' were perfectly correct.

In the diagram before given* (p. 62) we see how the Llandeilo Flags with the trilobites, Asaphus tyrannus and others, as exposed in lofty crags (Craig-y-Glyn) overhanging the gorge of the river Twrch above Llanrhaiadr, dip under those shelly sandstones of the lower hills of the valleys of the Tanat and Ffyrnwy rivers†. The latter strata, though affected, like those on which they rest, by a slaty cleavage, were described as again emerging from beneath Upper Silurian rocks in the environs of Welsh Pool, and were all, as before said, distinctly identified with the shelly sandstones of Caer Caradoc. This comparison was a subject of no difficulty, for it was evident that the sandstones of Montgomeryshire, with their included courses of impure limestone, including the Trinucleus Caractaci, Orthis (now Strophomena) expansa, and numerous other fossils, were identical with the shelly sandstones of Caer Caradoc.

In short, through other undulations (see Map and Sections) these beds extend westwards until they constitute the slates of the summit of Snowdon, where the very same fossils occur as in the low hills of soft shelly sandstone in Shropshire, the district from which such forms were first described.

In South Wales we have the same physical order and the same

* From a coloured section, Sil. Syst. pl. 32. f. 9.

† It is now evident why, in the year 1834, when I made the hasty visit of a day to Bala with Professor Sedgwick, I expressed an opinion that the rocks of that place were not of the Llandeilo formation, since they contained none of the characteristic Llandeilo trilobites! The few fossils I then saw at Bala were enclosed in rocks so slaty, and so unlike those of Caer Caradoc, that I might well be deceived; the more so, as the strata, dipping to the east, passed under the mass of the Berwyns, and therefore seemed to underlie certain flags which I had previously recognized to be of true Llandeilo age.

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changes in organic life between the Llandeilo and Caradoc groups. In Carmarthenshire and Pembrokeshire the Llandeilo Flags, with their large Asaphi and Ogygiæ, are surmounted by sandy beds with impure limestone, containing the same species of fossils as the shelly sandstones of Caer Caradoc.

Seeing that in Carmarthenshire there was no apparent unconformity towards the east and south between the Llandeilo Flags and the Upper Silurian rock, under which they dipped, as exhibited in the Sections, p. 57, 58, I formerly inferred that the equivalent of the Caradoc Sandstone of Shropshire had locally thinned out to the south and south-east of Llandeilo, or was there represented by certain coarse sandy beds or grits only. Again, detecting scarcely any trace of organic remains to the west and north of the zone in which the Llandeilo Flags were dominant, I drew a line of limit on my original map, and termed all the rocks Cambrian which lay beyond the known fossil zone; stating, that the separation of the Silurian from the Cambrian of South Wales had been generally effected by assigning to the former those beds which contained, and to the latter those which did not include, the characteristic fossils (Sil. Syst. p. 360). And yet, such sections as were made towards the west and north-west indicated that the strata of Carmarthenshire, on the right bank of the Towy, folded over to the north and west, and constituted a mass of arenaceous and incoherent slaty schists, which were spoken of as lithologically inseparable from the Lower Silurian rocks (Sil. Syst. p. 360).

It is not my object in this volume to describe the mines which occur in the Silurian or other paleozoic systems; but it may be noticed, that the chief mines in Carmarthenshire, or the lead ores at Nant-y-Moen, north of Llandovery, the property of Earl Cawdor, occur in these quartzose rocks which alternate with slaty schist. They are now ascertained to be in part the equivalents of the Caradoc Sandstone of Shropshire; and in part even of the Llandovery Rocks to be described in the ensuing Chapter. In similar rocks are situated the old Roman gold-mines of Gogofau, ten miles west of Llandovery*. In describing these rocks of slaty quartzose grit and sandstone, I accurately assigned to them the dip to the north-west†; and that fact alone ought to have led me to class them as Silurian, since they appeared to overlie the Llandeilo Flags. But the slaty condition of the rocks, and the absence of fossils, induced me to refer them to a system unknown to me. A great fault was, indeed, supposed to intervene, to account for this apparent inversion. These rocks were further noticed, as containing coarse grits, sandstones, and

* See Sil. Syst. p. 367, and Mr. Warington Smyth's account of these mines, Records of Geol. Survey, vol. i. p. 480. † See the woodcut, Sil. Syst. p. 368.

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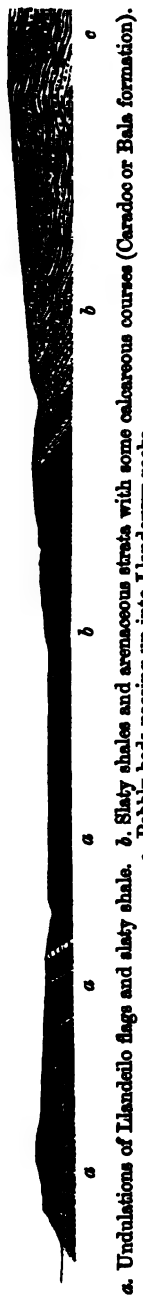
RELATIONS OF THE LLANDEILO AND CARADOC OR BALA ROCKS (S. WALES)†.



a. Undulations of Llandeilo flags and slaty shale. b. Slaty shales and arenaceous strata with some calcareous courses (Caradoc or Bala formation). c. Pebbly beds passing up into Llandovery rocks.

conglomerates—the latter often appearing as huge lenticular masses.

The only organic remains detected during my very partial survey of such strata were a few fragments of Crinoids and shells, and the Annelide markings or tracks of marine worms found near Llampeter, such as the Nereites and Myrianites*. These fossils are now known to be common to Silurian rocks in Scotland, Germany, and other parts of the world.

In their laborious and accurate researches, the Government Surveyors established clear proof, that, whilst on the left bank of the Towy a great portion of the Caradoc or Bala formation is omitted, the hilly tracts to the north and west, *i.e.* on the right bank of the stream, which had been called Cambrian, afforded clear indications of a gradual and conformable *upward* passage from the Llandeilo Flags into schistose beds. These, becoming more arenaceous and siliceous as they rise into higher hills, contain some calcareous courses, the fossils of which are all identical with those of the Caradoc or Bala rocks.

This section, as taken from the large horizontal published section of the Survey, was made, in the year 1842, by Professor Ramsay. The fossils he then collected and sent to London have been examined by Mr. Salter since the first edition of this work.

* See Sil. Syst. pp. 363, 699, and Chap. X. of this work. Geinitz, of Dresden, who has described these forms, considers them to be soft-stemmed creatures of the same family as Graptolites (Nereograpsus, &c.).

† It was this section (as I have recently learned) which led Sir H. De la Beche and Prof. Ramsay to abrogate the hypothetical line formerly drawn between a known Silurian country and one unexamined and unknown by me; and to show that a very large portion of the latter, so far from being low in the Silurian System, is really superior to the Llandeilo Flags.

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The great mass of the strata above the Llandeilo Flags, as seen in ascending the Nant-y-Rhibo Brook to Cwm-y-gerwn, consists of dark sandy shale with some calcareous matter containing the following fossils, all of which are of true Caradoc or Bala age: viz. Trinucleus seticornis, His.; Staurocephalus Murchisoni, Barr.; Orthis insularis, Eichw.; O. Actoniæ, Sil. Syst.; O. vespertilio, id.; O. calligramma, Dalm. and Sil. Syst.; Leptæna transversalis, Dalm.; L. quinquecostata, M'Coy; L. tenuicincta, id.; Turbo crebristria, id.; and the chain-coral. Proceeding to still higher ground, extending to Tyn-y-Mynydd, we meet with other forms; for while there are still a few Caradoc fossils, such as Orthis crispa, M'Coy, and the remarkable trilobite Encrinurus multisegmentatus, Portlock, these are associated with the Atrypa reticularis, a shell which uniformly characterizes the higher zone to be presently described under the name of Llandovery Rocks. Again, the highest beds visible in this line of section indicate still more clearly a passage into the Llandovery Rocks. Thus, in them we detect the Atrypa crassa, Leptæna transversalis, a Rhynchonella closely resembling R. navicula, and a large Heliolites, all unknown in the inferior or true Caradoc strata, one of the fossils of which, however (the Orthis insularis), still remains, as if to demonstrate a gradual zoological transition.

On the left bank of the Towy, in the wooded grounds of Llandovery, we again find the Llandeilo beds regularly surmounted by slaty and arenaceous beds which, underlying the conglomerates at the base of the Llandovery series, are full of characteristic Caradoc or Bala fossils. Thus, in Cilgwyn Park, under the conglomerate terrace of Glan Towy, the beds, which are quarried in the demesne, consist of dark grey, earthy slates, and contain the following characteristic fossils,—identical with those forms which are met with everywhere upon the banks of the Onny, or at Bala:—

Trinucleus seticornis; Asaphus Powisii; Illænus Bowmanni, with species of Calymene and Cybele; Strophomena spiriferoides, M'Coy; Orthis biforatus; O. insularis; Nucula; an Orbicula (the Patella Saturni of Portlock), a species known at Cheney Longville, and in the Caradoc schists of Tyrone, Ireland; Bellerophon bilobatus; B. nodosus; Theca triangularis, Portl.; Sphæronites balticus; and a beautiful new species of Glyptocystites, with some of the ordinary corals.

The same Caradoc beds also range round under Blaen-y-cwm, S. of Llandovery. They there contain similar fossils, with the addition of Lichas laxatus, M'Coy, the Orthis porcata, id., and the Orthoceras Ibex,

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Sil. Syst., now known to range from the Caradoc to the uppermost Ludlow rocks. Further north, between Rhayader and Builth, the Caradoc strata everywhere appear beneath the Llandovery rocks; and at Troed-y-Rhiw the same fossils are obtained, including a new and peculiar Crinoid, the Glyptocystites, together with the Bellerophons and the Orthoceras vagans so common at Bala.

Thus we have in that tract an unbroken ascending series from the Llandeilo flags through the Caradoc into those beds with Pentameri, which I formerly grouped with the latter formation, and which are, indeed, essentially connected with it.

In Pembrokeshire also, at Llampeter Felfry and Llandewi Felfry, the Llandeilo flags, constituting the thickest limestones known in the Silurian rocks of Wales, occur, as already stated, in low undulations, dipping under strata which also stand in the place of the Caradoc. (See diagram, p. 56.)

A thin and impure calcareous course of the latter, exposed at Sholeshook near Haverfordwest, and which has been hitherto classed with the Llandeilo flags*, is now also clearly separated from that deposit, both by superposition and characteristic organic remains. Besides brachiopods, trilobites, and numerous corals common in the Bala beds, there are also found in it Encrinite-like forms with slender stems and grape-shaped heads, the Sphæronites of old authors (Cystideæ of Von Buch). Some of these will be figured and described in another chapter; Echinosphærites aurantium and E. Balticus, both of them common Russian and Scandinavian species, being among the number.

In the vast tracts of Carmarthen, Cardigan, Radnor, and Montgomery, to the west of the original Silurian region, which have been examined by the Geologists of the Survey, and illustrated in their large coloured sections, it is believed, that few or no rocks older than the Caradoc or Bala formation, or younger than the Lower Llandovery rocks of the next chapter, ever appear—even up to the sea-cliffs extending from Cardigan to Aberystwith; so much do the same bands of sandstone and schists (usually affected by a transverse cleavage) undulate in gentle curves. There are, indeed, proofs, in several tracts, that these rocks, as in the district north of Llandeilo, graduate upwards into the Pentamerus zone of Llandovery, the

* Sil. Syst. p. 387.

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inferior and larger portion of which belongs essentially to the Lower Silurian division.

When the first edition of this work was published (1854), it was still the belief of geologists that Llandeilo and Bala were synonymous terms; and, although the inferences which have since been arrived at rest greatly upon the true order of superposition as eliminated by Ramsay and Aveline, we are also greatly indebted to the paleontologist, Mr. Salter, who has cooperated in establishing the true sequence. On my own part, I claim no other credit than that of having originally placed the Llandeilo formation beneath all the deposits of the age of the shelly sandstones of Caer Caradoc,—an order which, being first pointed out in parts of Montgomeryshire and Denbighshire, has now been applied to the whole of Wales*.

Throughout large portions of North Wales, there are, indeed, other evidences of the age of the rocks in question, besides those already adduced on the east flank of the Berwyns. At and near Bala, for example, the sandstones, slates, and limestones are the absolute equivalents of the Caradoc shelly sandstones in Shropshire. The chief limestone of this group, exposed in low hills near the town and lake of Bala, is so impure, that it is now never used for burning, and, dwindling away to the S.S.W., is lost among the slaty strata. Another calcareous course, near Hirnant, may be simply one of the shelly sandstones of Shropshire. Thus, with the exception of having been affected by a slaty cleavage unknown in the English types of these rocks, the North Welsh strata are, to a great extent, lithologically similar to the Caradoc formation of Shropshire.

The fossils of the Bala beds are, as already said, identical with those imbedded on the flanks of Caer Caradoc; there being scarcely a species found in Wales which does not occur in Shropshire.

Sufficient proofs having been now offered of the superposition of the Caradoc to the Llandeilo rocks, and the fossil characters of

* In the first edition of this work, I endeavoured, in spite of my old convictions, to accommodate my views to those of my successors, who had considered Llandeilo and Bala as synonyms, and therefore suppressed my old section from the flank of the Berwyns to Welsh Pool. But I now revert to the original details and descriptions given in the 'Silurian System,' which are clear and demonstrative, as before stated, in identifying the great undulating masses of strata in the Welsh region watered by the Tanat and Ffyrnwy rivers, as well as the Welsh Pool ridge, with the shelly sandstones of Caer Caradoc.

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the two formations having been generally indicated, we might at once proceed to consider the distinctions of the next overlying zone, which hitherto I have also grouped with the Lower Silurian rocks. But as I now regard those strata as an intermediate deposit, the larger and inferior portion of which is naturally connected with the Lower, and the higher member with the Upper Silurian, a separate chapter will be devoted to the subject. In the mean time, however, a few pages must be occupied by a sketch of the igneous or pseudo-volcanic masses which alternate with the mass of the Lower Silurian strata.

Igneous Rocks associated with the Lower Silurian.—To make the reader acquainted with the complete aspect and nature of the British Lower Silurian rocks, it is essential to explain how volcanic action affected the bottom of the sea in certain districts during the deposition of those sedimentary strata, and how those strata were also penetrated by powerful eruptions.

In the vicinity of some igneous rocks, the schists and calcareous flagstones have also been filled with mineral veins, and have undergone various changes*. Thus, one of the tracts in the original Silurian region where the Llandeilo formation is most productive in lead ore is the rugged, hilly district of Shropshire which lies around the village of Shelve and the Corndon Mountain, and extends westwards, from the Stiper Stones (see Section, p. 86, and Map).

The student of natural phenomena is again specially invited to examine this tract, the ordinary strata of which, and their organic remains, have before been described, because it exhibits all the cotemporaneous formations of North Wales, in hills which are much more accessible than the steep flanks of the slaty, subcrystalline mountains of Snowdon and Cader Idris.

This typical Lower Silurian district was long ago shown by me to contain two classes of submarine igneous rocks; the one bedded and regularly interlaced with the strata, and therefore formed cotemporaneously with them; the other unstratified or amorphous. Each of these is divided into several varieties, for a full acquaintance with which the reader must consult the original descriptions†.

* Besides ores of lead and copper, it will be also shown, in a separate chapter, that rocks of this age were rendered partially auriferous in Wales, and largely so in other countries.

† See Sil. Syst. pp. 269, 324, and *passim*.

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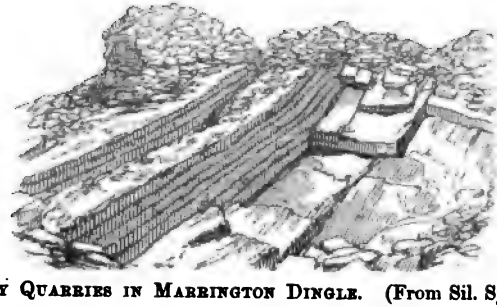
Of the stratified or bedded felspathic ash (volcanic grit of the 'Silurian System'), there are very numerous examples between the west flank of the Stiper Stones, where they first appear in the ascending order, and the picturesque defile of Marrington Dingle near Chirbury on the west; or in other words, through a space of four to five miles in breadth, and eight to nine miles in length (see Sil. Syst. p. 268).

At the Bog Mine, on the western slope of the Stiper Stones, and therefore in the lowest member of the Llandeilo formation, the mineral veins and adits traverse a vast number of the thin-bedded felspathic grits or ashes, interstratified with the schists and flags charged with trilobites and graptolites. Not less than seventeen courses of these felspathic igneous rocks are marked in the Government Geological Map of this district (Sheet 60) as occurring in the space of little more than a mile, between the Bog Mine and the environs of Hyssington! Some of these courses are traceable for four miles on their line of bedding. They crop out in parallel rocky ridges, whilst the associated schists and shales have been worn into alternating furrows or depressions. The broadest of these felspathic ash bands, as seen upon the surface, ranges from near Symmonds Castle on the S.S.W. by the Roundtain Hill to Stapeley; beyond which, or between Shelve and Rorington, it is divided into five or six of the thinner courses, interlaminated with the Llandeilo Flags. Among the higher members of these stratified ashes, which were manifestly accumulated under former seas, some of the finest examples are to be seen in the picturesque defile of Marrington Dingle. There, the lowest strata, exposed in numerous quarries, are felspar rocks of a concretionary structure, which are surmounted by coarse mottled volcanic grits. The latter consist of a base of lightish and greenish-grey granular felspar, mixed with sand and chlorite, and contain angular fragments of schists and porphyritic greenstones; the whole being arranged in beds from two to four feet thick, and dipping at an angle of about 40°, as expressed in this vignette.



WHITTERY QUARRIES IN MARRINGTON DINGLE. (From Sil. Syst. p. 270.)

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In many other parts of this district, we meet with felspathic agglomerates and ash-beds, or volcanic grits, as well as slaty porphyries with crystals of felspar. Some of these alternate, as before said, in ridges with the schist containing trilobites; others constitute courses of a few inches thick only, and occasionally include fragments of the Ogygia (Asaphus) Buchii. Organic remains are also found in beds composed almost exclusively of igneous materials; thus showing that volcanic action was rife at the sea-bottom in which these Lower Silurian strata were accumulated. The annexed woodcuts will convey some idea of the manner in which the volcanic breccia or ash, *b*, which alternates with the beds of schist, *a*, envelopes other fragments of schist and slate, *c*.

(From Sil. Syst. p. 271.)

Another diagram, taken from the coloured sections on the margin of my old map of the Silurian region, explained theoretically the manner in which, by the action of submarine volcanos, such igneous dejections were supposed to have accumulated. The igneous or volcanic materials are represented by the light-coloured layers, *a*, *a*,

IDEAL REPRESENTATION OF THE MANNER IN WHICH SUBMARINE VOLCANIC DEJECTIONS PROBABLY WERE FORMED DURING THE LOWER SILURIAN PERIOD.

(From bottom of Map, Sil. Syst.)

which alternate with the ordinary dark-coloured muddy sediment. The diagram further shows, how a volcanic cone similar to that of Graham Island (Ile Julie of the French) in the Mediterranean, and indicated by the dotted lines, may, after rising into the atmosphere,

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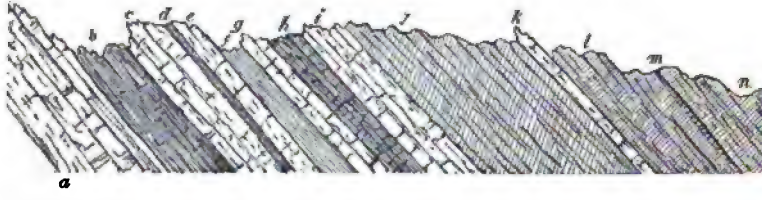
have disappeared and mixed its scoriæ and ashes with the ordinary submarine mud or sand.

One of the larger masses of eruptive trap, which subsequently penetrated the sedimentary and associated volcanic deposits at a subsequent period, is seen in the Corndon Mountain, as expressed in this view, the undulating ground around it being composed of strata of the Llandeilo formation and beds of felspathic ashes.

LOWER SILURIAN AND BEDDED TRAP, TRAVERSED BY ERUPTIVE ROCKS; THE CORNDON MOUNTAIN IN THE DISTANCE.
(From Sil. Syst. p. 271.)

Equally instructive examples of the alternations of bedded igneous matter with Lower Silurian strata, and also of posterior eruptions, are seen in the rocky tract of Radnorshire, extending from Llandegley and Llandrindod by the hills of Gelli, Gilwern, and Carneddau, to Builth. This example of the felspar porphyries, which are there regularly stratified, is taken from one of my former illustrations.

ALTERNATIONS OF LLANDEILO FLAGS AND SCHISTS WITH VOLCANIC GRITS. N.W. FACE OF GELLI HILL.
(From Sil. Syst. p. 325.)



a. Coarse slaty felspar rock, both porphyritic and amygdaloidal, containing elongated concretions of green earth. This rock is regularly stratified in beds of three to four

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feet thick, and forms the mass of the hill, rising into the higher ground. *b*. Finely laminated greenish-grey sandy flagstone, apparently hardened near the top. *c*. Fine-grained granular felspar and courses of clay-stone, some of which are used as oven-stone. *d*. Altered flags, having a conchoidal fracture, in parts almost Lydian-stone, with crystals of iron pyrites. *e*. Grey felspar rock, the laminæ of deposit marked by ferruginous streaks, probably due to the decomposition of some other mineral. *f*. Black shivery shale, containing a few concretions of argillaceous limestone, with veins of calcareous spar. One of these, which fell under my notice, was a septarium, two or three feet in diameter, containing many impressions of *Graptolites*. This band of black shale was excavated to a considerable distance in search of *coal*! on the strike of the beds, by the same individuals who have sought for lead ore. *g*. Hard, thick-bedded porphyritic felspar. *h*. Flagstone, with *Ogygia Buchii*, indurated in contact with the trap; much iron pyrites. *i*. Grey porphyritic clay-stone. *j*. Black schist, with some hard stone bands, in parts pyritous. *k*. Slaty porphyritic felspar. *l*. Black shale, with stone bands and concretions of argillaceous limestone. *m*. Thin band of decomposed granular felspar, weathering to a rusty colour, and looking like a coarse oolite. *n*. Black pyritous schists, much contorted near the mouth of the gallery.

Thus, in a thickness of only 350 feet across the beds, this detailed section of the order exhibited in one of the original typical Silurian tracts displays felspathic and porphyritic rocks, occasionally both crystalline and amygdaloidal, with clay-stone, granular felspar, &c. These materials alternate, six or seven times, with finely laminated flagstones and black schists, containing Graptolites and the Ogygia Buchii (Pl. III. f. 1). In truth, therefore, this little section exhibits an epitome of the structure of vast tracts in North Wales.

The intrusive rocks which have broken through and diversified these tracts of Shropshire, Montgomeryshire, and Radnorshire, now under consideration, whether large masses or mere dykes that traverse the contiguous strata, were most of them laid down in the map of the Silurian region, and have since been more accurately defined by the Government Surveyors (*vide* Sheets 60 & 61). They are chiefly coarse-grained, hornblendic greenstones and felstones, some of them passing into basalt. In many cases, the shale or schist in contact with the eruptive rock has been converted into porcellanite, with surfaces smoother than the finest lithographic stone. These altered shales are, in fact, the 'Brand-erde,' or burnt-earth, of the Germans* (Sil. Syst. p. 275).

The Breidden Hills, including the picturesque Moel-y-Golfa, on the right bank of the Severn, near Welsh Pool, also exhibit similar illustrations, both of cotemporaneously bedded ashes and of erup-

* In England, curious *actual* proofs of this conversion occur in the South Staffordshire coal-field, near the town of Dudley, where the long-continued combustion of subterranean coal in abandoned mines has converted the associated shale and sandstones into burnt-earths, or porcellanites, of divers colours; some of them resembling the riband-jasper of mineralogists.

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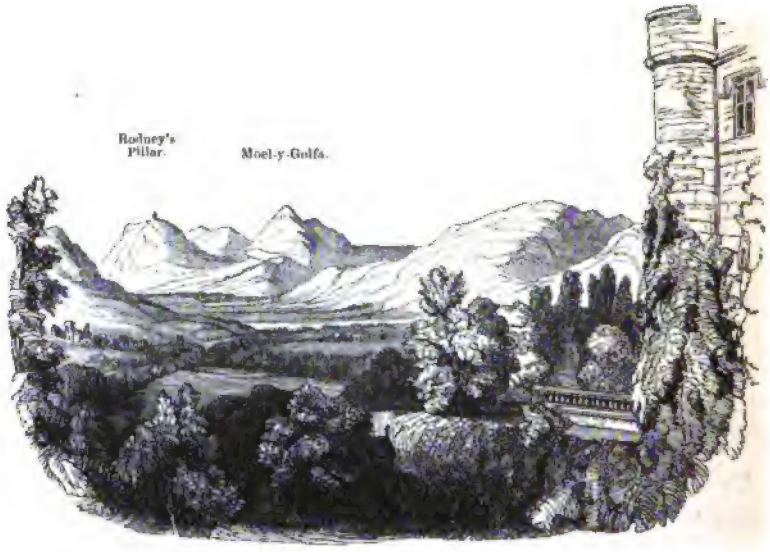
tive or intrusive rocks, which have broken out along the same line at different periods*.

The annexed drawing, taken from the terrace of Powis Castle, shows these hills in the distance to the north-east. They mark a line of eruption that separates the Lower Silurian rocks, on the left hand, from the Upper Silurian of the Long Mountain on the right. Now, it has been demonstrated that along this line of



VIEW OF THE BREIDDEN HILLS NEAR WELSH POOL, FROM POWIS CASTLE.
(From a Drawing by Lady Murchison, Sil. Syst. p. 302.)

eruption, ranging from S.W. to N.E., some volcanic dejections were spread out on the sea-bottom during the formation of the Lower Silurian strata, and that other eruptions and dislocations afterwards took place along it, heaving the strata into highly inclined positions, like those on which Powis Castle stands. It further appears, that on the edges of these Silurian and volcanic rocks, carboniferous deposits were afterwards accumulated; and that again, after all these and other formations, including the New Red Sandstone and Lias, were completed, still more recent eruptions occurred along this same line of fissure†, as indicated by

* See detailed descriptions, Silurian System, p. 287 *et seq.*
† For the proofs of this, see Sil. Syst. p. 299 *et seq.*

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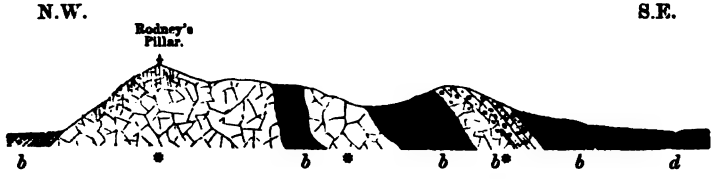
trap dykes which traverse those secondary formations to the N. of Shrewsbury.

The shortest method of explaining to the reader the structure of the Breidden Hills is to exhibit this small diagram. It represents a mass of porphyritic and amygdaloidal greenstone, which in its protrusion has carried up included portions of slaty rocks, and has thrown off pebble-beds and Upper Silurian rocks to the S.E., and Lower Silurian to the N.W.

SECTION ACROSS THE BREIDDEN HILLS.

(Taken from a Section by Mr. Aveline of the Geological Survey.)



b. Lower Silurian slaty rocks. *b**. Cotemporaneous trap breccia. *d*. Wenlock shale or base of Upper Silurian. * Eruptive rocks.

One of the igneous rocks most easily examined on this line of habitual outburst in ancient periods, is the large basaltiform mass at Welsh Pool, which cuts as a dyke through the Lower Silurian strata, and has much altered them. At a little distance, however, from the trap, those beds contain organic remains; some of them, particularly the Trinucleus concentricus or T. Caractaci (see Pl. IV. f. 2–5).

This prismatic, igneous rock is largely quarried as a building-stone, like that of the Whittery Quarries. It is remarkable in having its light-green felspar matrix abundantly speckled with minute kernels of calcareous spar, which, being mixed with the finely aggregated felspar, renders the rock a sectile and valuable free-stone.

Other eruptive greenstones as well as hypersthene rock, cut through Silurian strata near Old Radnor†; but, as they are associated with strata of younger date than those we are now considering, they will be more appropriately mentioned in another chapter.

On the flanks of the Carneddau Hills, between Llandrindod and Builth, there are, however, amorphous masses of igneous rock, which have broken through and highly altered the Llandeilo flags. Beautiful examples of this are seen on the banks and in the bed of the Wye, west of Builth. (See Sil. Syst. p. 332 *et seq.*)

On this occasion one diagram only is selected from the plates of my large work, to show, first, how the strata of the Llandeilo formation alternate with bedded igneous rocks, *b**, and next, how they have been

† Sil. Syst. p. 318.

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altered in contact with eruptive masses, *. It is in these black and hardened schists along the lines of contact that films of anthracite were found, which led credulous farmers to search for coal†.

SECTION ACROSS THE GELLI HILLS.

N.W. (From Sil. Syst. pl. 33. f. 5.) S.E.

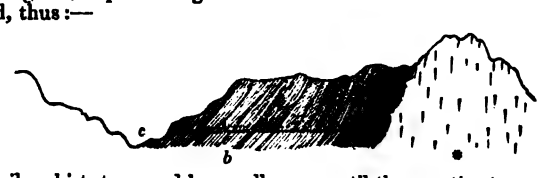
b. Llandeilo flags. *b**. Llandeilo flags with interpolated cotemporaneous felspathic ashes, &c. * Eruptive rocks.

Another frequent result, in this district, of the intrusion of the igneous rock into the schists is the production of much sulphuret of iron, the decomposition of which gives rise to the various mineral sources of Llandegley, Llandrindod, Builth, Llanwrtyd, &c., that gush out around or near to this volcanized tract.

In North Wales, some of the finest examples of the stratified and cotemporaneous beds of felspathic ash or volcanic grit are exhibited in the environs of Festiniog. There, the interval between the green and grey schists, of the age of the Lingula flags of Tremadoc, and certain overlying black roofing slates is occupied by syenite, satiny schists, and volcanic grits; the last being partly coarse conglomerates. To the west of Tan-y-bwlch, these beds assume the form of ashes, which are there very finely levigated, and differ from talc schist in being less quartzose. They are associated and alternate with hard grit, penetrated by large branching veins of white quartz.

Occasionally, this felspathic ash is separated into thick beds formed of slightly inclined laminæ of deposit, and is traversed by numerous highly inclined lines of slaty cleavage, from which the associated coarse grits are exempt.

† A full exposure of this folly was given in the 'Silurian System,' p. 328, with this diagram, representing an actual search after coal! at a spot called Tin-y-Coed, thus:—



b, Llandeilo schists traversed by a gallery, *c*, until the eruptive trap-rock, *, was reached, where the *coal* enterprise was necessarily stopped.

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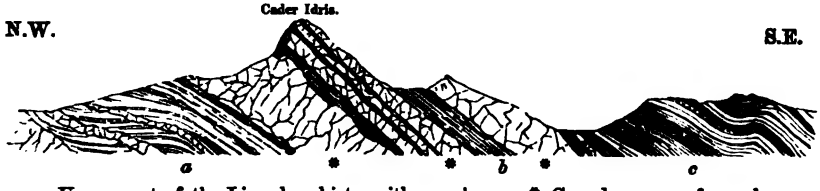
An adequate acquaintance with such features can be attained only by traversing those mountains with the remarkable illustrations of the Geological Survey in hand†. In the area of a few square miles, the geologist there meets with numerous grand alternations of interstratified volcanic ashes and felspathic conglomerates, sometimes sandy and calcareous, which have been pierced by eruptive igneous matter, whether syenite, felstone, or greenstone, here and there porphyritic‡. It is, indeed, sometimes most difficult to separate the cotemporaneous igneous rocks (porphyries of Sedgwick) from the subsequently intruded masses.

Then, again, let the student take in hand the minutely-worked maps of these districts, and, observing the faults or fractures as delineated on them by the great number of white lines, he may form some idea of the consummate skill and labour by which such results have been obtained.

This brief sketch of the igneous operations which were the accompaniments of the Lower Silurian sediments cannot, indeed, be better terminated than by exhibiting two woodcuts, reduced from the large horizontal sections of the Survey, which record the labours of Ramsay and Selwyn in North Wales. The first of these diagrams represents the relations of the different rocks composing the mountain of Cader Idris, near Dolgelly.



a. Upper part of the Lingula schists, with porphyry. * Grand masses of porphyry and other trap rocks, with courses of hard slaty Lower Silurian schists, *b*. *c*. Lower Silurian, assuming its ordinary characters of shale when removed from the igneous rocks.

† The repeated alternations of these pseudo-volcanic rocks with the schists and slates of North Wales can alone be well understood by reference to the maps and sections prepared by Ramsay and Selwyn. See Sheets 75 and 78 of the Geological Survey, and the illustrative horizontal Sections of the same on the six-inch scale. In the small Map attached to this work, and which, as before explained, is simply a reduction of that of the Government Surveyors, numberless details are necessarily omitted.

‡ A fine example of this succession to the north of Festiniog was pointed out to M. de Verneuil and myself by Professor Ramsay in 1851; the real merits of whose labours will very shortly be made known in one of the Memoirs of the Geological Survey.

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SECTION ACROSS THE SNOWDON RANGE. (From Horizontal Section No. 23, Geological Survey.)
Snowdon, 3571 feet.

a. Cambrian grey and purple grits and slates, much dislocated and supporting Lingula flags. *b*. Lingula flags, faulted. *c*. Slates (Llandeilo), dark grey, traversed by greenstone dykes, * (the bedding almost obliterated), followed by *d*, bluish-grey and brownish sandstone and slate (lower part of Caradoc) with felspathic ash and volcanic grit, *d**. *e*. Upper part of Caradoc or Bala beds, fossiliferous, with calcareous and felspathic ashes.

The lowest strata here indicated, *a*, are slaty schists, containing a few Linguláe; they have been traversed by porphyry, *, and towards their summit contain some layers of felspathic ashes. Then follow grand masses of porphyry and greenstone, *, which alternate with Lower Silurian slates, probably of the Llandeilo age, *b*, and some accompanying ash-beds; whilst the overlying slates and schists, *c*, are superior portions of the Lower Silurian rocks, which resume their ordinary characters when removed from the igneous foci of which Cader Idris was a great centre of action.

In examining this mountain, we see that the crystalline and slaty strata on its flanks, *b*, are succeeded by other masses, *c*, which in proportion as they recede from the igneous rocks partake more of the character of 'mudstone.' This character prevails, indeed, wherever the strata are unaltered, from the base of the Silurian system to the very youngest of its beds.

The opposite section developes the structure of Snowdon, and shows to what an extent the sediments constituting the highest mountain in England and Wales have been modified. Independently of the slaty cleavage by which large portions, and particularly its western flanks, have been impressed, as seen in the fine lines which cut across the beds, under the word y-Tryfan, the student will perceive, that rocks

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inferior to any which are sketched in the section of Cader Idris (p. 91) are here represented†.

The strata, *c*, which constitute the lower portion of Snowdon, and repose upon the older slates and Lingula flags, *b*, consist of dark bluish-grey slaty schists, representing the inferior part of the Llandeilo formation. In them, however, no clear fossil evidences have been detected. They are traversed by masses of eruptive rock *, which, whether consisting of porphyry and greenstone or compact felspar or felstone, have been described by Sedgwick, and their elaborate relations have been defined by Ramsay. In following, however, these same beds a few miles to the environs of Ffestiniog, we meet with the fossils of the lower member of the Llandeilo formation already indicated, and thus the age of the whole mass is suggested. In the next overlying accumulations, *d*, we already find many Caradoc fossils, although the original beds alternate rapidly with volcanic dejections of ashes and felspathic materials.

Truly grand as are these igneous features of North Wales,—and similar phenomena, though on a less scale, occur in South Wales (Pembrokeshire),—they are, I repeat, precisely of the same character as those of the western hills of Shropshire, described as the true Lower Silurian types, and the age of whose volcanic eruptions was established by the associated organic remains. In like manner, we now know, through their imbedded fossils, that the slaty, arenaceous masses, with their beds of ashes, constituting the summit of Snowdon were formed at the very same time as the humbler hills of shelly sandstones on the eastern flank of Caer Caradoc.

† Professor Ramsay's observations on these igneous phenomena in N. Wales, which he has elaborated with great ability and precision, will be better appreciated by consulting his forthcoming publication in the Memoirs of the Geological Survey, which is specially recommended to the attention of geologists. He assigns good grounds for the belief, that, although some of the intruding bosses and dykes of porphyry, syenite, and greenstone were posterior to the sedimentary felspathic and other volcanic ashes which they traverse, others probably represent the deep-seated portions of the volcanic centres from whence flows and ejections of felspathic lava took place during the Lower Silurian epoch. He also infers that all those igneous rocks were formed during the older Silurian period, commencing at the close of the deposition of the Lingula beds. He establishes this important inference by pointing out, that the intruded masses have all been subjected to subsequent forces which bent, contorted, and fractured those ancient accumulations. Hence the interstratified ashes and the intrusive rocks both pertain to the same great Lower Silurian epoch. (See also Quart. Journ. Geol. Soc. vol. ix. p. 170, 1853.)

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CHAPTER V.

LLANDOVERY ROCKS—(TRANSITION FROM LOWER TO UPPER SILURIAN).

THE FORMATION SHOWN TO BE ONE OF INTERMEDIATE CHARACTER, AND CONTAINING BOTH LOWER AND UPPER SILURIAN FOSSILS WITH SOME PECULIAR TYPES.—ASCENDING ORDER OF THE WHOLE GROUP NEAR LLANDOVERY IN SOUTH WALES, WHERE MOST DEVELOPED.—THE UPPER PORTION ALONE EXHIBITED IN RADNORSHIRE, SHROPSHIRE, HEREFORDSHIRE, THE MALVERN HILLS, MAY HILL, TORTWORTH, THE LICKEY HILLS, ETC.—THE VARIETIES OF THE BASE OF THE UPPER SILURIAN ROCKS OF WALES.

In my earlier publications, the whole group of strata to which attention is now invited was placed at the summit of the Lower Silurian rocks. The progress of research and the labours of my cotemporaries have now led me to admit, that whilst the lower and larger portion of this formation is related, through numerous organic remains, as well as by physical arrangement, to the inferior half of the system, the higher member, though also containing some of the inferior types, is, by many of its fossils, more naturally connected with the Upper Silurian*. At the same time, the formation is eminently characterized throughout by certain Pentameri peculiar to it, which are not known either in the subjacent or superjacent deposits, and also by some species of other shells which never rise into the Wenlock, or true Upper Silurian rocks. A short, separate chapter is therefore devoted to the consideration of this group; showing its intermediate character and varied development in different localities.

Though not recognizable in the northern or central parts of the Silurian region, the inferior member of the formation is fully exposed in extensive tracts of S. Wales to the north and west of Llandeilo, and particularly near Llandovery, where it was formerly described in detail†. Let us first, then, consider the nature and

* This last feature was first pointed out by Professor Sedgwick and Professor M'Coy in their memoir on the May Hill Sandstone (Phil. Mag. ser. 4. vol. viii. 1854, p. 301).

† Sil. Syst. p. 351.

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contents of these rocks as seen in ascending order in the last-mentioned tract, where both their members are exposed, and afterwards treat of them in certain districts, where the lower member of the group is wanting and the uppermost subdivision alone is visible.

In the first edition of this work, all these rocks were termed 'Upper Caradoc'; but that term is now set aside. The local name of Llandovery Rocks is taken from the district where clear physical relations are seen of the transition from the Caradoc or Bala formation beneath, up into the lower member of these deposits; and from the latter into the upper band of the formation. The table of colours attached to the Map, and the accompanying brackets, explain the nature of this link; and the geologist who examines the various tracts of country described in these pages will understand, how the lower masses of the formation may be best classed with the Lower, and the higher strata with the Upper Silurian rocks.

Reverting to the natural section where the flags of Llandeilo (p. 79), to the north of the town of that name, are overlaid by the equivalents of the Caradoc or Bala formation, it has been observed, that there the strata of the latter graduate upwards into coarser sandstones, occasionally conglomeratic, in which a few Pentameri have been found. These last-mentioned strata, though containing few fossils, extend, as already mentioned, over considerable tracts of South Wales, where they really form the summit of the Lower Silurian rocks.

On the left bank of the Towy, and particularly in all the tract extending from the River Sowdde to Noeth Grüg north of Llandovery, these sandstones and shales, with a conglomerate at their base, and also resting on Caradoc rocks, prevail in a range of hills, whence many characteristic fossils were procured and published in the 'Silurian System'*. It was formerly stated, that in the environs of Llandovery this sandstone had not the durability and firmness of the Caradoc sandstone of Shropshire, and was not so easily separable from those Upper Silurian rocks from beneath which it emerged in the wooded hills near that town. The formation was, however, shown to be loaded with many fossils of true Lower Silurian character, derived from Rhiwfelig, Blaen-y-cwm,

* The collections were chiefly made by my respected friend the late Mr. Williams, Surgeon, of Llandovery, and his son, now the Rev. Stewart Williams.

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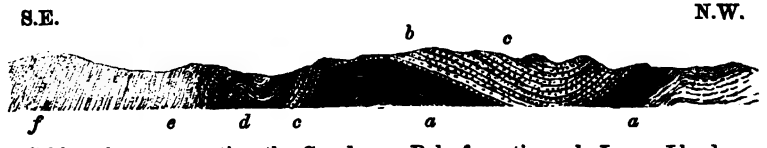
Cefn Rhyddan, and Goleugoed; the last-mentioned locality, whence the Llandovery building-stone is extracted, having afforded most of the species.

The following fossils figured in the 'Silurian System,' are repeated in Plates 8, 9, 10, 11: viz. Orthoceras bisiphonatum; O. approximatum; Lituites undosus; L. cornu-arietis; Pleurotomaria (Turbo) Pryceæ; P. (Buccinum) angulata; Holopella (Turritella) cancellata; Rhynchonella (Terebratula) pusilla; R. neglecta; R. tripartita; Orthis lata, including O. protensa; O. calligramma; O. Actoniæ; O. elegantula; Atrypa crassa; A. reticularis; Pentamerus lens; P. globosus; P. undatus; P. oblongus, or lævis; Strophomena depressa; Leptæna sericea, &c. &c.*

In following these rocks to the north-east, by Llandovery, through the elevated moory grounds of Mwmfre, they are seen to become more quartzose, and to rise up into the bare and stony hills of Noeth Grüg and Cefn-y-garreg about 1500 feet above the sea, where the whole formation is admirably exposed, as in this diagram†.

NOETH GRÜG. (From the Government Survey.)



a. Schists, &c., representing the Caradoc or Bala formation. *b*. Lower Llandovery rocks (Llandovery sandstone). *c*. Upper Llandovery rocks: equivalent of the May Hill sandstone. *d*. Tarannon shale, or 'pale slate,' of which hereafter. *e*. Wenlock and other Upper Silurian strata, without subdividing limestones. *f*. Base of Old Red Sandstone. (Compare with Sections, Sil. Syst. pl. 34. f. 3.)

Wild and uninhabited, this small tract is truly remarkable in being the only one in England and Wales wherein the lower and upper zones of the Llandovery or Pentamerus rocks have as yet been observed in one united mass, and with clear relations to the inferior and superior strata. In the last chapter a succession from the Caradoc formation into the lower members of this group was,

* Several names of fossils given in the 'Silurian System,' p. 351, &c., are here omitted, as more perfect specimens have shown that those forms belong to some of the species here named. The names of two or three genera have also been changed; but the types remain the same.

† I revisited this locality since the first edition of this work, in company with Earl Ducie, Prof. Ramsay, and Mr. Aveline. The latter has furnished me with a more accurate section than any one hitherto published: it does not, however, differ essentially from the original section given in the 'Silurian System.'

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indeed, indicated as occurring over large districts of the west of Carmarthen and Cardigan. But there the upper member of the Llandovery rocks seems to be wanting, and no overlying Upper Silurian strata are contiguous, as in this district. In the bare and rocky undulations around Noeth Grüg, no unconformity is observable between the underlying beds, or the representative of the Caradoc formation, and the strata surmounting them, which are laden with Pentameri and other fossils of the group under review. Nor is any discordance visible either between the lower and upper Pentamerus rocks or between the latter and the overlying Upper Silurian strata. What then is the age and equivalent of the lower and larger portion of the hard gritty sandstone (*b*)? If mineral aspect be considered, this rock would certainly be ranked as one of high antiquity; for the softer and more argillaceous sandstone and building-stone of Llandovery has in the short intervening distance become a hard intractable grit, traversed by planes of slaty cleavage, as shown in the white lines of the drawing.

Again, if the fossils of the lower beds of these sandstones be appealed to, we find in them, either at this or other localities, the following unquestionable Lower Silurian types:—Illænus Bowmanni, Salter; Lichas laxatus, M'Coy; Murchisonia simplex, id.; Orthis insularis, Eichwald; O. calligramma, Pl. 5. f. 9; O. Actoniæ, ib. f. 11; Strophomena bipartita, Salter; Leptæna sericea, Pl. 5. f. 14; Turbo crebristria, M'Coy; Lituites cornu-arietis, Pl. 7. f. 10; Orthoceras bilineatum, Hall. See also woodcuts in Chap. 8.

In addition to these forms, none of which rise higher in the series than the zone under consideration, the following species, which are also of Lower Silurian date, range upwards through all the Llandovery rocks into undoubted Upper Silurian or Wenlock. These are: Atrypa marginalis, Pl. 9. f. 2; Orthis elegantula, f. 19; O. occidentalis, Hall; Strophomena antiquata, Pl. 20. f. 18; S. pecten, Dalm.; Conularia Sowerbyi (quadrisulcata, Sil. Syst.), Pl. 25. f. 10; Bellerophon dilatatus, f. 6; Orthoceras ibex, Pl. 29. f. 3. (See Plates 8 to 11, and woodcuts in Chaps. 8 & 9.)

There are other fossils which occur in both the Lower and Upper Llandovery rocks, such as Leptæna sericea, Orthis reversa, Rhynchonella furcata, R. angustifrons, Raphistoma lenticularis, Holopella cancellata, Petraia subduplicata, and P. elongata. The chief character, however, which unites the lower and upper members of this formation, besides the community of these and other species, is the great abundance

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of Pentamerus, Atrypa, and Petraia,—and the absence of all, or nearly all the characteristic trilobites of the subjacent deposits.

The upper member of the group, *c*, as seen on the summits and slopes of the hills of Noeth Grüg and Cefn-y-garreg, has always seemed to me (even in a close re-examination in 1856) to form the regular and conformable capping of the lower strata, *b*. In it we not only find the continuance of the same hard, gritty, lithological character and colour of the stone, but also the same distinguishing fossils, the Pentameri, of which the Pentamerus oblongus becomes much more abundant and characteristic, though still accompanied by P. undatus and P. lens (see Pl. 8). Figures of the other fossils of this zone, including the Atrypa hemisphærica, A. reticularis, Bellerophon trilobatus, Encrinurus punctatus, and Petraia subduplicata, will presently be given in describing the range of these Upper Llandovery or Pentamerus rocks through Shropshire and other tracts, where the above types are associated with Upper Silurian fossils.

Upper Llandovery Rocks in Radnorshire, Shropshire, Herefordshire, &c.—In quitting this typical tract, and in proceeding to the north and east, or to the S.W., the Geologists of the Survey have everywhere observed a marked absence of the lower member of the Llandovery rocks, and have ascertained that the upper zone with Pentamerus oblongus is alone present, and forms the natural base of the Upper Silurian rocks.

Thus, in Radnorshire, this upper zone is represented by a thin course or two of sandstone or conglomerate, occasionally resting, as near Builth, in striking unconformability on the upturned edges of the Llandeilo flags. That tract, it will be remembered, like the district of Shelve and Corndon in Shropshire, is replete with igneous rocks, and in both, the Llandeilo formation appears to have been raised from beneath the waters, and not to have been depressed or again subjected to any marine action during the whole period when the Caradoc formation was accumulating. Such relations are strikingly exhibited in the diagrams already given at p. 62.

In tracing the relations of the Caradoc sandstones of Shropshire to the overlying shale and limestone of the Wenlock Edge, I was formerly led to believe in the existence of an unbroken ascending series. This appeared to be the case on the banks of the Onny, where that river flows from Horderley on the N.W. to Wistanstow on the S.E. I then saw that the lower beds of the Caradoc formation were highly inclined in the proximity of the igneous rocks of Caer Caradoc, but that the inclination decreased gradually to the east; so that the flagstones of Cheney Longville, which were described in the last chapter, seemed to

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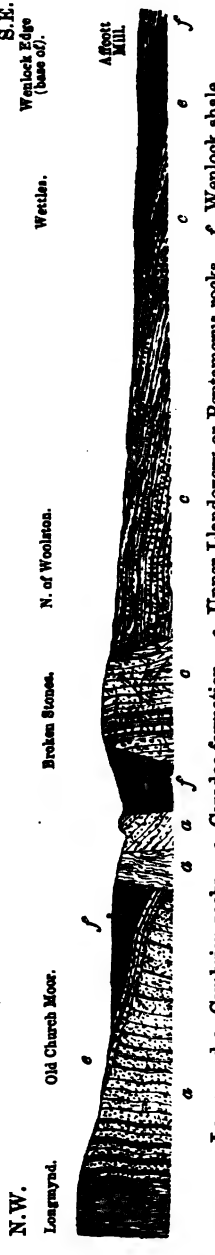

RELATIONS OF THE UPPER LLANDOVERY (PENTAMERUS) ROCKS TO THE INFERIOR AND SUPERIOR DEPOSITS, BETWEEN THE LONGMYND ON THE N.W., AND THE FOOT OF WENLOCK EDGE ON THE S.E. (From Horiz. Section 33, Geological Survey.)

a, a. Longmynd or Cambrian rocks. *a.* Caradoc formation. *e.* Upper Llandovery or Pentamerus rocks. *f.* Wenlock shale.

pass with apparent conformity under those beds of shale and limestone which contain the Pentamerus oblongus. Now, as I had found this same characteristic fossil in strata of South Wales which graduate downwards (as already shown) into rocks with Lower Silurian forms, and had never detected it in the overlying Wenlock shale; and further, as in the greater part of the Silurian territory, the strata which contained it are coarse *grits and sandstones*, resembling the inferior rocks, but wholly unlike the superior argillaceous formations of Shropshire and Herefordshire, I naturally classed the rock with the Lower Silurian.

Many years had elapsed—even the Geological Surveyors had also examined and mapped the district under consideration without perceiving a break, which was first detected in 1853 by the researches of Messrs. Aveline and Salter. These gentlemen observed a want of conformity between the great mass of the so-called Caradoc sandstone beneath and the Pentamerus rocks above; the latter being perfectly conformable to the Wenlock shale. The amount of unconformity, as seen in this woodcut, which is taken from the published sections of the Government Survey, is greater than that which can be detected on the line near Wistanstow, on which the succession was originally noted by myself*.

This diagram exhibits not only the Upper Llandovery or Pentamerus rock reposing in one place upon the truncated edges of the Cambrian or Longmynd rocks, *a*, and in another place trans-

* The amount of this discordance on the Onny is so slight, and the banks of the river at the point of junction are so overhanging, that the slightly transgressive arrangement of the strata can only with great difficulty be ascertained, and that when the river is very low; at other times the river must be waded to see the break.

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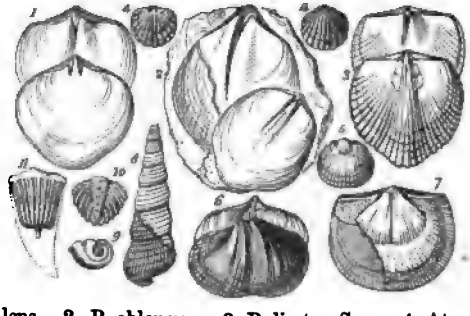
gressive upon the true Caradoc, *c*, but is further highly expressive of the powerful fractures or faults by which the typical region has been affected at periods long subsequent to all those movements of the subsoil which produced the unconformable deposition of the strata.

When this country was examined by me in 1832–3–4, it was, indeed, considered, that the powerful outbursts of igneous matter, seen in the contiguous eruptive ridge of Caer Caradoc, might well account for all such partial dislocations; and as the uppermost of the shelly sandstones at Cheney Longville clearly dipped under the Pentamerus zone or Hollies limestone, and this last passed under the Wenlock shale, the general order of superposition, notwithstanding the adjacent disturbances, could not be doubted. See the preceding general woodcut.

The fossils which most characterize this member of the deposit in Shropshire, as elsewhere, are the Pentameri, and particularly P. oblongus and P. lens, with Atrypa hemisphærica, Rhynchonella decemplicata, and Strophomena compressa. With these, however, there are other species, some of which occur in the Lower and many others in the

UPPER LLANDOVERY FOSSILS (14).



1. Pentamerus lens. 2. P. oblongus. 3. P. liratus, Sow. 4. Atrypa hemisphærica. 5. A. reticularis. 6. Pentamerus undatus. 7. Strophomena compressa. 8. Holopella cancellata. 9. Bellerophon trilobatus. 10. Encrinurus punctatus. 11. Petraia subduplicata, M'Coy.

Upper Silurian rocks. Among the former are some of the species already enumerated, viz. Leptæna sericea, Orthis calligramma, O. biforata, Turbo crebristria*, and all the species above mentioned (p. 97) which range from

* I have not here mentioned the Trinucleus concentricus (Caractaci) and the Orthis vespertilio, both highly characteristic Caradoc fossils, which were formerly quoted as occurring in this deposit (Siluria, p. 87), because, although these species were found by Mr. Salter in the zone under consideration, he believes that they must have been transported as fragments from the subjacent Caradoc shale. This point requires further examination.

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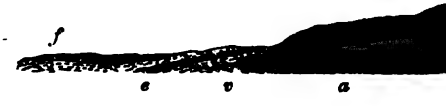
the Lower into the Upper Silurian rocks. The species common to this zone and the overlying formations are Bumastus Barriensis, Phacops Downingiæ, P. Stokesii, Atrypa reticularis, Pterinea retroflexa, Goniophora cymbæformis, Bellerophon trilobatus, and B. expansus, &c.

The woodcut, Foss. 14, exhibits those fossils only which are truly typical of the Llandovery rocks. Some of these forms, however, are so abundant in the Lower Silurian as well as in this zone, and so rare in the Wenlock formation or base of the Upper Silurian, that they still give a distinct impress to the deposit.

In Shropshire, this zone of Pentamerus rock varies much in dimensions. When followed to the N.E. from the banks of the Onny, where it is a thin calcareous course only, it so swells out in the parishes of Church Preen and Kenley, that a considerable thickness of sandstone and conglomerate is there interposed between the shelly sandstone of Caer Caradoc and the Pentamerus limestone. Both these villages, as described in the 'Silurian System,' stand upon coarse grits with white quartz pebbles, in parts almost a conglomerate, the beds rising at a low angle from beneath the Hollies or Pentamerus limestone and the overlying Wenlock shale, to both of which they are conformable. The chief fossil in this coarse grit and conglomerate is the Rhynchonella decemplicata (Pl. 9. f. 15). These rocks also range up to the south-eastern flank of the Wrekin, and dip with the Pentamerus limestone under the Die earth, or Wenlock shale, of Buildwas and the gorge of the Severn.

On the south flank of the Longmynd, this zone, whether in the form of a pebbly conglomerate or of an impure limestone, both charged with Pentamerus oblongus, reposes at a low angle of inclination on the ancient rock, as thus represented in my old work.



(From Sil. Syst. pl. 32. f. 4.)

At the spot to which this diagram refers, copper veins, *v*, are seen to penetrate both the subjacent Longmynd rock, *a*, and the overlapping Pentamerus rock, *e*; the last being overlaid by Wenlock shale, *f*.

In another part of Shropshire, the rock is seen to protrude along a line of fault as an isolated patch through the Wenlock shale of Brampton Bryan Park, and is again visible further to the S.W. at two points in Radnorshire; the one in a dome to the south of the town of Presteign, the other on the western slopes of the hill of Old Radnor. (See Map.) In these examples it is a quartzose, pebbly conglomerate, passing into a hard, coarse grit (Corton), in which casts of the Pentamerus oblongus and other fossils occur, such as Atrypa hemisphærica, Petraia elongata, and P. bina. Along this line it is also obviously the lowest bed brought up in domes and arches by the line of igneous eruption,

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along which the hypersthenic and felspathic rocks of Stanner, Hanter, and Ousel have been evolved. These outbursts have so altered the contiguous sandstones, schists, and grits (just as around the Wrekin and the Caer Caradoc), that in Old Radnor Hill and Yat Hill it is difficult to determine which parts of the masses are metamorphosed rocks resulting from the effect of volcanic eruption, and which have really been in a molten state. The diagrams illustrating this phenomenon, including the metamorphosis of the limestone of Nash Scar, will be given in the sixth chapter, which treats of the Wenlock formation.

In that district of Radnorshire, the Upper Llandovery rock is a siliceous grit and conglomerate, and is at once conformably surmounted by shale and limestone, which, from their fossils, are grouped as the lower member of the Wenlock formation of the Upper Silurian rocks, or Woolhope limestone, as will be hereafter described.

Malvern Hills.—Again, on the western flank of the Malvern Hills we meet with sandstone and conglomerate characterized by the above-mentioned fossil Pentameri. As these rocks have there, according to Professor Phillips, a thickness of 600 feet, and have peculiar relations to the rocks on which they repose, as well as to those under which they dip, a few pages may be instructively devoted to a sketch of the leading features of that striking ridge of hills.

This picturesque Silurian tract, which is detached from the main region over which rocks of this age are continuously extended,

VIEW OF THE MALVERN HILLS FROM THE WEST.
(From a sketch by Lady Murchison, Sil. Syst. p. 409.)

is composed of the undulating grounds which lie upon the western flank of the Malvern Hills. The accompanying vignette represents the Herefordshire Beacon on the right hand, followed by the

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Worcestershire Beacon and the North Hill in the distance, as seen from the undulating grounds composed of Upper Silurian rocks which occupy the western flank of the ridge, the highest parts of which are exclusively composed of crystalline rock, both eruptive and metamorphic.

Though occupying a much narrower zone than in the typical tract of Shropshire, the Silurian rocks constitute an almost continuous band, from the northern end of the Abberley Hills to the southern extremity of the Malvern Hills, a distance of about twenty-four miles. Throughout this space, the beds strike, on the whole, from north to south and dip rapidly to the west, by which they pass under the Old Red Sandstone of Herefordshire*. In the northernmost part of this line of elevation, or the Abberley Hills, no rock of truly eruptive character is seen except at one spot west of Martley, where, many years ago, I detected a small boss of syenite, identical in character with the chief eruptive rock which protrudes in large masses on the summits and slopes of the Malvern Hills.

That crystalline ridge, essentially of igneous origin, was well described by Mr. Leonard Horner in the infancy of English geology. The prevailing rocks are varieties of syenite, consisting of quartz, felspar, and hornblende; and occasionally, where the last-mentioned mineral is absent, presenting the appearance of a true granite. Of the other minerals epidote is most disseminated. Again, compact felspar rock or felstone is abundant, and passages from it into syenite and greenstone are not unfrequent. These amorphous rocks have evidently intruded upon certain stratified deposits which, usually in a highly altered condition, adhere to the flanks and sides of the syenitic chain. They consist of chloritic schist, quartzite, and highly twisted micaceous schist, almost passing into gneiss. Examples of the conversion of the original Lower Silurian sandstones and shale into such metamorphosed rocks are here and there exposed.

In the mean time, let us see to which of the lower divisions of stratified rocks these inferior strata are referable.

* On the east all these rocks are flanked by the Trias, or New Red Sandstone, the divisions of which have been laid down in the Sheets 43 & 55 of the Geological Survey Map. See also the memoirs by the Rev. W. S. Symonds, Journ. Geol. Soc. vol. xi. p. 450; and Edin. New Phil. Journ. vol. v. p. 257.

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The lowest of the unaltered deposits which have been termed Silurian by Professor Phillips and myself is the Holly-bush Sandstone, and this is overlaid by certain schists, both of which are in parts so black as to have given the name of Coal Hill to some hilly arable ground to the west of Keys End Hill (see note †, p. 105).

These lower strata of sandstone and black shale extend from north to south along the slopes of Midsummer Hill, Ragged-stone Hill, and Keys End Hill, or the southern portion of the chain, for a length of upwards of two miles, and have an average width of half a mile from east to west, in which space they are perforated, here and there, by small bosses and dykes of intruded greenstone, as laid down in the Map of the Survey*.

The inferior sandstone is well displayed in quarries at the 114th milestone on the road from Tewkesbury to Ledbury, where the beds dip away from the part of the ridge called Ragged-stone Hill at an angle of 35°. This rock, of a light greenish tint, and containing a small portion of mica, is freckled with a few dark stains, but has afforded no organic remains save fucoids. The lower beds are thick, but become flag-like upwards, and pass through sandy shale into overlying thinly foliated, black shivery schists.

These schists were described in the 'Silurian System' (p. 416) as possibly belonging to the Llandeilo group; that suggestion having been made, in the absence of any known organic remains, from the strata being surmounted by a zone of sandstone with Pentameri, then termed Caradoc Sandstone, followed by a full Upper Silurian series. Subsequently, Professor Phillips discovered in these schists the small trilobite Olenus humilis; and afterwards my lamented friend Mr. Hugh Strickland detected the minute Agnostus pisiformis. The occurrence of these forms, so emblematic of the lowest zone of Silurian life (see Foss. 6. p. 46), has led me to believe that the Holly-bush sandstone and associated schists are the miniature representatives of the Stiper Stones of Shropshire and the Lingula flags of Wales. In another chapter, and when treating of the Silurian rocks of Norway and Sweden, it will be proved that the thickness of deposits is no test whatever of their age, nor of the time which may have elapsed during their accumulation. The hundred feet or two of Holly-bush sandstones and black schists now under consideration may, in short, as M. Barrande has indeed suggested, be the equivalents *in time* of strata thousands of feet thick already adverted to in Shropshire and Wales.

The sandstone and black schist, which constitute the lowest fossil-bearing sediment of the tract, are thrown off to the east as well as to the west of the eruptive or syenitic chain at Midsummer Hill, S. of the

* These protuberances of trap-rock were first noticed by Professor Phillips.

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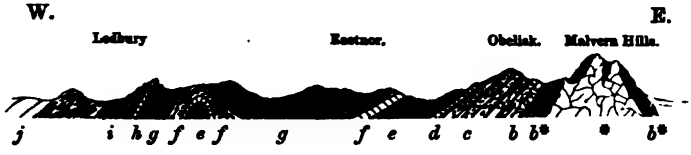
Hereford Beacon. This is seen in traversing the ridge near its south end, from Keys End Street on the east, by the White-leaved Oak, to the hilly arable ground on the west. The Malverns are therefore represented in the following diagram as exhibiting a geological saddle, having a thin and partially metamorphosed flap only on the east side, and several thick flaps on the west, the lower part of one of which only is in an altered condition. Among the older strata visible on the east flank, are the same black schists subordinate to sandy flags, which on the western slope of the ridge of syenite have given to the ground the name of Coal Hill†, and in which the species of Olenus and Agnostus already mentioned have been sparingly detected.

The reader will understand the facts by consulting this little general diagram‡.

SECTION FROM THE MALVERN HILLS TO LEDBURY.



This woodcut, taken from a coloured section in the 'Silurian System' (pl. 36. f. 8), and slightly modified, explains the general order and the undulations on the west side of the Malvern Hills, in the parallel of Midsummer Hill, Eastnor Park, and Ledbury. The eruptive rocks, *, of the Malvern ridge on the right are seen to be flanked, on both sides, by altered Lower Silurian sandstones and schists, *b**. To the west these are followed by other schists with Olenus, *b*. The Upper Llandovery rocks and conglomerate are marked by *c*, the higher portion of which dips down from the Obelisk Hill of Eastnor, and pass under the Woolhope, or Lower Wenlock limestone, *d*. The latter is followed by the Wenlock shale, *e*, and the Wenlock limestone, *f*, which last, bending under the Lower Ludlow, *g*, reappears in a dome that throws off towards Ledbury the whole of the Ludlow formation, *h i*, after a flexure in Wellington Heath, under the Old Red Sandstone, *j*.

Although it is not within the scope of this volume to describe in detail the former effects of eruptive molten matter in transmuting the character and condition of the sediments through which it burst forth, still I would beg any geological student who has the power to examine this natural section. He will see that as the strata flanking the ridge on either side approach to its central part, or axis of igneous rocks, they gradually become more hard and brittle, and that, their flag-like character gradually ceasing, the beds pass into thick amorphous masses, in which the lines of bedding are lost, and the substance is much altered and fissured by many devious joints with serpentinous coatings. The nucleus or eruptive mass, exposed in the extensive quarries of Midsummer Hill, near the White-leaved Oak, is compact felspar, passing

† Absurd trials for coal have been made by ignorant persons in this black Lower Silurian shale *on both sides* of the eruptive axis.

‡ See Sil. Syst. p. 418, and coloured section, pl. 36. f. 8.

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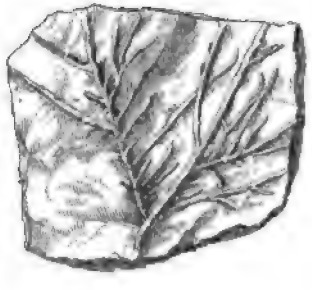
into syenite; but the northern extensions of this same eruptive ridge, particularly as displayed in the Worcestershire Beacon and North Hill, contain other varieties of the igneous rocks already spoken of*.

The next deposit met with in ascending order upon the west flank of the Malverns consists of grits, conglomerates, and sandstones, occupying, as before said, a thickness of 600 feet; the chief localities being Howler's Heath, Cowley Park, the west of Hereford Beacon, the Wych, &c. The forms usually characteristic of this band of the Upper Llandovery rocks are the Pentameri before noted, Atrypa hemisphærica, Rhynchonella decemplicata, together with some of the univalve shells and corals previously mentioned as occurring at Llandovery. Of the latter, the Petraia subduplicata, M'Coy, is abundant, and Orthis calligramma is not unfrequent. The zone is here specially characterized by a number of bivalve shells allied to Nucula, of which the N. Eastnori and N. subæqualis (Pl. 10. f. 7, 8) are examples. The last-mentioned species and its associates, Bellerophon trilobatus and Holopella obsoleta (ib. f. 14), pass upwards, as will be seen in the sequel, to the uppermost Ludlow rock.

One of the shells highly characteristic of the Llandovery rocks in this district is the Lingula crumena, Phill., which was figured by mistake amongst the fossils of the true Caradoc formation, 'Siluria,' 1st edition, p. 86. Foss. 7. f. 5. Even the peculiar Crustacean, Pterygotus, which, as we shall presently see, is eminently an uppermost Silurian form, has its representative here in fragments which were found S. of Eastnor Obelisk by the late Mr. Hugh Strickland.

It is also worthy of notice that a perfect cast of a fucoid was found in a fragment of this rock on the west side of the North Hill by the well-known and zealous botanist Mr. Edwin Lees, and as vegetable remains are rarely found in these deposits, the specimen is here figured.

FOSSILS (15).



Fucoid in Malvern Sandstone.

The rock, in the form of a dingy purple grit with a superjacent flaggy limestone, ranges from the End Hill of Malvern to Old Storridge Hill, and is seen for the last time in Ankerdine Hill, the most southern of the Abberley Hills. Throughout its course along the west flank of the Malverns, where it rests upon the eruptive rocks, and thence to the gorge of the Teme, under Ankerdine Hill, this sandstone, with its impure

* It was gratifying to me, in a recent visit with Professor Ramsay, to observe that this minute point of the syenitic axis, which I first observed in 1852, was still visible in the bottom of the quarries; for doubtless it may now be hidden by debris, and subsequent observers might be sceptical.

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limestone, constitutes the regular base of all the Upper Silurian rocks which dip away from it to the westward. On its eastern flank, on the contrary, the same rock is brought into abrupt contact (see Map) with the New Red Sandstone by that great longitudinal (north and south) fault which runs along the whole length of the Malvern and Abberley Hills*.

In delineating with great precision the order of the strata as well as their flexures and breaks, Professor Phillips discovered†, on the west side of the Worcestershire Beacon, that one of the local conglomerates, then called Caradoc, and charged with several characteristic fossils, contained also pebbles and fragments of the syenite and other eruptive rocks of the Malvern chain. Hence it was evident, that along this line there had been eruptions which had left a shore or island of hard rock from which the conglomerate in question had been derived. It is, therefore, to be inferred that the eruption at the White-leaved Oak and Keys End Hill, to which attention has been called, took place at a more remote period, and even that the erupted matter traversed the oldest Silurian strata of the tract, or the Holly-bush sandstones. This agency having ceased, a low ridge seems to have been raised and placed beyond the influence of the depositary action going on in other places, where the Llandeilo and Caradoc formations were accumulating. In short, the Malvern ridge was then left, to be acted upon by the sea, so as to furnish materials for the completion of a younger deposit.

The elevation of the Malvern Hills in a solid state, and at a later period, together with the folding back of the strata, so as partially to invert the order and place the Upper Caradoc grits *over* the Wenlock shale, and the latter over the limestone (a phenomenon first pointed out by Mr. Leonard Horner‡ as due to the uprise of the syenite), is one of great interest, which occurs on a vast scale in the Alps and many other mountain-chains.

Passing from the consideration of these physical features, other

* This fault is one of the longest that has been traced in the British Isles. On its eastern side the various members of the Silurian series above enumerated are seen in some places to be overlaid by the Old Red Sandstone. In other localities the Silurian rocks subside, and the Old and New Red are in contact as between the Abberley and Malvern. In its range southwards, the fault is marked by a band of Permian conglomerates; and still further to the south, or towards May Hill, a thin zone of coal-measures separates the New Red of Gloucester from the Old Red of Hereford. See Sheets 43 & 55 of the Geological Survey, in the last of which the relations of other and oblique transverse faults to this great longitudinal fracture are clearly laid down.

† Memoirs Geol. Survey, vol. ii. p. 66. Miss Phillips made this discovery.

‡ This overthrow of the strata, together with an excellent account of the mineral structure of the Malvern Hills, was first given by Mr. Leonard Horner, Geol. Trans., old series, vol. i. p. 281. The nature and succession of the overthrown beds were illustrated in detail by myself, 'Silurian System,' p. 423, and lastly by Professor Phillips, Memoirs Geol. Survey, vol. ii. p. 67 *et seq.*

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natural appearances on the flank of the Malvern Hills, described by Professor Phillips and myself, show how difficult it is to draw any definite line between the Llandovery rocks, formerly Upper Caradoc, and the lowest portion of the overlying Wenlock shale. To the west of the Worcestershire Beacon, or near the north end of the chain, there occurs an impure limestone, occupying nearly the same position at the summit of the Llandovery rocks, and known as the Hollies limestone of Shropshire (pp. 100, 101). This bed contains some fossils which truly belong to the lower group, such as Leptæna sericea and Orthis calligramma, and possesses many others which are characteristic of the Upper Silurian division.

The reader should compare my original description* of this intermediary band of limestone, as it ranges by Stumps Wood and other places west of the Malverns, with the more precise details of Professor Phillips.

The Upper Silurian rocks of this tract have been here partially alluded to only, p. 105; my object being to show how very different is the succession of strata *beneath* them, to that which occurs in Shropshire and Wales, where the series is full and complete. It must, however, be said, that few tracts in England afford better examples for the study of the upper members of the system, as indicated in the little section, p. 105, to some features of which the attention of the reader will afterwards be called†.

The insulated district of Woolhope, within a short distance of the Malvern Hills, exhibits the smallest portion only of the Upper Pentamerus rock in the centre of that remarkable valley of elevation, which displays the whole of the Upper Silurian rocks, and will be treated of in the sequel. It is well, however, here to note, that the major axis of that elevation is from N.W. to S.E., and consequently at right angles to the main direction of all the Silurian rocks in Wales and the border counties of England, and also discordant to the N. and S. line of the Malvern Hills.

* See Sil. Syst. p. 415. In his luminous memoir of the Malvern and Abberley Hills, and their extension to Woolhope, May Hill, &c., Professor Phillips has skilfully and elaborately developed all the physical contortions of the strata in this district, and the mineral and paleontological characters of the rocks. By the sound philosophical reflections with which it is interspersed, he has imparted great value to a work, which reflects the highest credit on the Geological Survey of Great Britain.

† As the Malvern Hills are within easy access of the Lias of the vale of the Severn, and the Oolitic range which, extending athwart England from Whitby and Scarborough on the N.E. to Lyme Regis on the S.W., is so admirably displayed in the Cotteswold Hills and at Cheltenham, geologists have gratefully hailed the establishment of a Naturalists' Field Club and Museum at Great Malvern (in which the Rev. F. Dyson and the Rev. W. S. Symonds have taken a prominent part) for the purpose of registering all the phenomena in which this beautiful and diversified neighbourhood abounds. (See other references in Chapters VI. and VII.)

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May Hill Sandstone.—At a distance of about nine miles to the south of the Malvern range, the same deposit of Pentamerus sandstone, or Upper Llandovery rocks, reappears in May Hill and Huntley Hill, Gloucestershire, where it is equally surmounted by Upper Silurian rocks. We have just seen that in the S. Malvern section there is a great hiatus between this deposit and the fundamental stratified masses of the tract. Applying the same test to May Hill by ascending from the lowest visible rocks, we meet with a much greater omission.

This ascending order is best exposed on the sides of the high road passing from Gloucester to Ross, near the village of Huntley. In approaching the higher ground, the first rock which is observed to jut out from the plain of the New Red, or Keuper, has the aspect of the Cambrian rocks of the Longmynd. It is a hard, siliceous, close-grained, dark grey, schistose stone with quartz veins, and is quarried for the use of the roads. Containing no fossils and being much broken and contorted, this rock has no visible connexion with the overlying sandstones and shale which are exposed in ascending May Hill, in none of which are there any traces of either the Llandeilo or Caradoc (Bala) formations, or even of the Lower Llandovery rocks.

The mass of the hilly ground as exposed on the sides of the high road and ranging across Huntley Hill consists first of purplish and green shales and sandy beds passing into hard coarse grits, and yellowish, fine, micaceous sandstones, occasionally undulating, but on the whole dipping steadily to the W.N.W. These beds are chiefly characterized by the Atrypa hemisphærica, Orthis calligramma, Rhynchonella decemplicata, with some Pentameri. They are surmounted by reddish and lightish grey sandstones and grits in which the Pentameri abound, particularly the P. liratus and P. lens, with Atrypa reticularis, Strophomena pecten, and S. arenacea; and these strata, occupying the dome and summit of the hill, throw off certain grey flagstones to the west. Now, most of the species in these higher beds belong unquestionably to the Wenlock, or base of the Upper Silurian group. And such ought to be the case; for the upper flagstones in question pass up directly into strata constituting the true base of the Wenlock formation, as seen near Duraley Cross.

Among these fossils are Petraia bina, Palæocyclus porpita, Halysites catenularius (or the chain-coral), Cornulites, Encrinurus punctatus, Pentamerus oblongus, P. lens, Orthis calligramma and O. hybrida, Strophomena funiculata and S. pecten, Pterinea retroflexa, Mytilus mytilimeris, M. ovalis, Atrypa tumida, Rhynchonella borealis, Euomphalus funatus, Bumastus Barriensis, Phacops caudatus, and Beyrichia tuberculata or Klodeni.

On the other hand, the following species in these same beds and those of Huntley Hill *never rise into the Wenlock shale*: viz. Atrypa hemisphærica, Pentameri (four species), Rhynchonella furcata, Strophomena compressa, Tentaculites anglicus, Petraia subduplicata, and Lituites cornu-arietis. The last-mentioned fossil occurs in rocks of this age at Presteign, and has, indeed, been previously described as a Caradoc or Bala form.

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At the same time we see, that between this Pentamerus rock and all the inferior strata there is a much greater hiatus even than on the west flank of the Malverns. Infinitely less, in short, does the May Hill sandstone exhibit any feature of that close relationship with the lower deposits which is evident in the environs of Llandovery and Llandeilo.

The same north and south anticlinal which is apparent in May Hill and Huntley Hill, is continued southwards with a bend to the east at Pyrton Passage, and, crossing the Severn, it passes into the remarkable tract of Tortworth, where the Silurian rocks, emerging from beneath the Old Red and Carboniferous formations, have been long known to geologists. There, the elevation of the axial line being less considerable than in the Malverns or at May Hill, the oldest rock visible is the Upper Pentamerus sandstone with much trap rock, which, occupying a large area, is seen to be immediately surmounted by the Wenlock formation with two courses of limestone and feeble representatives of the Ludlow rocks*. (For details see Sil. Syst. chap. 34.)

The most eastern tracts in England where the Upper Llandovery rock has been raised to the surface are the Lower Lickey Hills in Worcestershire, and near Barr in Staffordshire, at both of which localities that rock supports the base of the Upper Silurian deposits of the adjacent tracts of Dudley and Walsall. At the Lickey, low heathy hills, in truth miniature mountains, are chiefly composed of quartz rocks, lithologically identical with those masses on the flanks of the Caradoc and Wrekin which have been formed by the fusion of sandstone. The Lickey quartz most probably owes its character to a similar cause; though in this case the igneous agency has not found issue at the surface in the form of trap rock, as at Dudley further north, or in Shropshire, where such igneous rocks are rife upon a similar axial line. In other words, the Lickey quartzite lies upon a line of former eruption. On its flank this rock graduates into an ordinary grit or sandstone, in which the Pentamerus lens occurs, and thus all doubt of its age is removed; whilst, just as in the other tracts above mentioned, this hard, siliceous sandstone, particularly on its eastern and southern parts (Colmers and Kendal End), is conformably surmounted by a calcareous shale with a thin course of limestone, which, as at

* Earl Ducie, who has made himself completely master of the structure and range of the rocks of this complicated district, so large a portion of which belongs to him, has also added much to our acquaintance with it, by collecting several species of fossils unknown to me when I published the 'Silurian System.'

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Woolhope, Corton near Presteign, and Old Radnor, contains Upper Silurian fossils.

Evidences have thus been given to show how certain portions of the Silurian strata are omitted in variable quantities in different districts. At May Hill, all the Lower Silurian rocks, including the Lingula flags, the Llandeilo and Caradoc formations, and even the Lower Llandovery rocks, are absent; the Pentamerus sandstone being there seen to repose at once on hard, unfossiliferous, slaty rock. At the Malvern Hills the lowest zone, or the equivalent of the Lingula flags, seems to be intercalated, but is succeeded at once by the Upper Llandovery rocks; the true Llandeilo and Caradoc being also excluded, as at May Hill. In Shropshire, no such great hiatus occurs; for there the original Caradoc formation exhibits a copious series of shelly sandstones (from 4000 to 5000 feet thick) rising from beneath the Pentamerus rock, which is not, however, connected with the subjacent mass.

The reader must here, however, be reminded, that in the original Silurian region there are large rocky districts of Shropshire and Radnorshire, as those of Shelve and Builth, in which the Llandeilo flags are not followed by the Caradoc rocks. That formation, of such large dimensions elsewhere, has there been entirely omitted, and the older deposit of Llandeilo is at once covered by a thin band only of the Upper Llandovery or Pentamerus sandstone, followed by the Upper Silurian shales. In those cases, it is manifest that powerful, but limited and local oscillations of the sea-bottom have taken place, by which the black muddy sediment, with its trilobites and shells, was raised up, constituting the Llandeilo flags, and was placed beyond the influence of the waters under which the true Caradoc sandstones were accumulated in so many other districts. But the older Llandeilo rocks so elevated, were again depressed beneath the sea, to receive on their upturned edges the accumulations of the Pentamerus band and the overlying Upper Silurian series (see Sections, p. 62).

The geologist who reasoned from such phenomena only, might be led to believe that a general break had occurred in the heart of the Lower Silurian rocks, or between the Llandeilo and Caradoc formations; but in this he would greatly err, for no such hiatus exists over a large region of Wales. On the contrary, by extending

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our observations, we find that the absence of the great Caradoc deposit in two or three tracts is, after all, a local phenomenon; inasmuch as we recognize the spread of that formation over a wide region of the Principality, where it lies symmetrically upon the Llandeilo rocks.

When the Upper Silurian rocks shall have been described, a set of tables will be placed before the reader, showing the omissions of certain strata in some tracts and their full sequence in others. In the mean time, let us remember, that whatever may have been the amount of disturbance of the ancient sea-bottom at the conclusion of the true Caradoc deposit, there are districts both in North and South Wales where no signs of such movements can be detected, but where all the sediments from the Llandeilo through the Caradoc to the Lower Llandovery rocks inclusive seem to have succeeded each other quietly, or at all events without exhibiting any rupture in their succession. Above all, it is to be recollected, that whatever may have been the amount of physical disturbance between the lower and the upper member of the Llandovery rocks, the organic remains of that formation unquestionably connect it with the Lower as well as the Upper Silurian rocks, and thus display a true transition from the inferior strata of which we have taken leave, into those overlying deposits whose structure and contents we are about to consider.

In illustration of the conformity apparently existing between certain strata which have hitherto been classed with the Lower Silurian, but are now determined by their organic remains to pertain to the base of the Upper Silurian, three sections are here offered.

In the former edition of this work, certain sections and their descriptions, as taken from the publications of the Geological Survey, though perfectly correct in delineating the physical data, call for another explanation.

On the revision of a large region of Wales by Mr. Aveline, under the direction of Professor Ramsay, the following points have been readjusted. In the first of these diagrams (given at p. 79 of the former edition), the title is changed from Llandeilo schists supporting Caradoc

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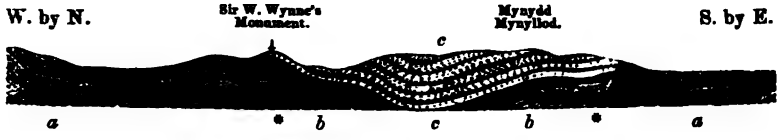
sandstone, into the Caradoc formation, *a*, supporting Tarannon shales, *b*, and Denbigh grits, *c*; the last-mentioned being known to contain Wenlock fossils, and therefore to be of Upper Silurian age. In this rectification the reader will see how important is that separation of the Bala

CARADOC OR BALA FORMATION SUPPORTING THE TARANNON SHALES AND DENBIGH GRITS (E. OF BALA). (Horiz. Sect. Geol. Survey, No. 35.)



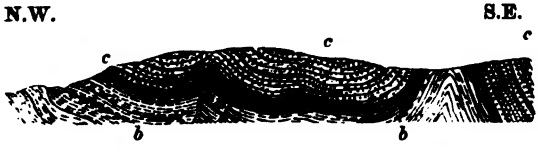
a. Caradoc formation with thin courses of Bala limestone. *b*. Tarannon shales or pale slates. *c*. Denbigh grits and shales lying in perfect conformity on the pale slates.

The slaty cleavage is partially represented by white lines. The dark traversing lines are faults, *, whereby the Upper Caradoc beds are lost.

from the Llandeilo formation, which has been so fully explained in the preceding pages.

In the next section, the lowest beds, *b*, are simply the Tarannon

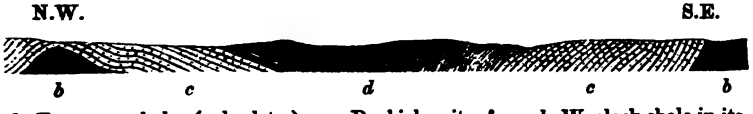
BORDERS OF RADNOR AND MONTGOMERY. (Horiz. Sect. Geol. Survey, No. 27.)



b. Tarannon shales or pale slates. *c*. Denbigh grits, with grey and blue schists.

shales or pale slates, which occupy an intermediate space between the Pentamerus or Llandovery rocks and the unquestionable Upper Silurian; the overlying grits and shales, *c*, like those of the previous section, forming the base of the Upper Silurian. Again, in the third section,

RADNORSHIRE, S. OF LLANBISTER. (Horiz. Sect. Geol. Survey, No. 27.)



b. Tarannon shales (pale slates). *c*. Denbigh grits, &c. *d*. Wenlock shale in its ordinary characters.

we have before us the true Wenlock shale, *d*, above all the masses exhibited in the previous sections.

The Tarannon shales, occasionally of hard, slaty character, and of various colours,—in some places so pale a grey as to have been termed

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'pale slates,' in others of purple colour,—have been shown by Mr. Jukes and Mr. Aveline to form a geological band of great persistence, which, beginning, according to the last-mentioned surveyor, in small dimensions near Llandovery, expands in its course through Radnor and Montgomery, and in N. Wales becomes an important subdivision. It is largely and clearly exhibited near New Bridge, and at Tarannon, between Llanbrynmaer and Llanidloes in Montgomeryshire. Fossils are rare, and those which occur do not absolutely determine whether the beds should be classed with the Upper Llandovery rocks we have been considering, or with the Wenlock formation. In a physical and geological sense, Prof. Ramsay and Mr. Aveline would class them with the latter. Mr. Salter would rather connect them with the Upper Llandovery rocks.

However this may be, the next band, *c*, which, from its mineral character, has previously been termed Caradoc sandstone, must clearly, through its fossils, be classed with the overlying shale, *d*, of the Wenlock formation. The sandstone, *e*, is, in short, known to be a prolongation of the 'Denbigh grits and flags,' which, from their being unconformable to the older slates and rocks, and containing Wenlock fossils, Professor Sedgwick properly considered to be the base of the Upper Silurian of N. Wales*.

Among the most abundant of these fossils there is, however, one form, Rhynchonella decemplicata, which is also characteristic of the Llandovery rocks. But with it are many common Upper Silurian fossils, such as Phacops Downingiæ, P. caudatus, Spirifer trapezoidalis, Cucullella ovata, Chonetes (Leptæna) lata, Murchisonia (Pleurotomaria) Lloydii, Bellerophon trilobatus, B. carinatus, Orthoceras annulatus, &c.

In the general Table of Colours attached to the Map, these 'Denbigh grits' are therefore placed at the bottom of the Wenlock formation. But as, with the exception of parts of North Wales, where the beds are sandy, the Wenlock formation is eminently distinguished by its purely argillaceous base, these exceptional examples have been first disposed of, and we now proceed to consider the Upper Silurian rocks from their base upwards, as developed in the original Silurian Region.

* Quart. Journ. Geol. Soc. vol. i. pp. 19, 21.

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CHAPTER VI.

UPPER SILURIAN ROCKS.

GENERAL CHARACTER OF THE UPPER SILURIAN ROCKS, AS DIVIDED INTO THE WENLOCK AND LUDLOW FORMATIONS.—THE WENLOCK FORMATION OF SHALE AND LIMESTONE, WITH ITS CHIEF FOSSILS, DESCRIBED IN ASCENDING ORDER, FROM THE SHALE WITH WOOLHOPE LIMESTONE TO THE WENLOCK OR DUDLEY LIMESTONE INCLUSIVE.

EXAMPLES have already been adduced to indicate the order in which the Lower Silurian rocks are overlaid by the higher division of the system; and we have now, therefore, to consider the mineral characters and fossil contents of the latter as composed, in ascending order, of the Wenlock and Ludlow formations.

As the older schists and slates were assuredly at one period nothing more than finely laminated, marine mud, so is it still more apparent that such was the former state of the greater portion of the Upper Silurian; for even at the present day the latter is composed of materials for the most part similar to those of the older slates, though in a softer and less coherent state.

Whether these argillaceous masses be examined in the wilds of Radnor Forest and the eastern parts of Montgomery, in the western parts of Shropshire (Long Mountain), or in many tracts of South Wales (see Map), they present the uniform 'facies' of a thick, yet finely laminated, dark, dull grey shale, in which hard stone of any strength or persistence is the rare exception. Their dominant character, in short, is that of 'mudstone.'

Ranging chiefly from S.W. to N.E., they rest conformably upon lower rocks, in numerous undulations*. Looking to the whole region in which these rocks are laid down upon the annexed Map,

* The strike of the same deposits varies in different districts. Thus, in North Wales, the prevalent strike is nearly N.N.E.—S.S.W. In the Wenlock and Ludlow district it is nearly N.E.—S.W.; whilst in S. Pembroke all the Silurian rocks range from W. by N. to E. by S., in conformity with the direction of the great South Welsh coalfield (see Map). The apparently conformable undulations of the Lower and Upper Silurian rocks in various parts of Wales are, indeed, represented in the diagrams already given, p. 113, as taken from the published horizontal sections of the Government Survey.

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there are considerable tracts of North Wales where the lowest members of the Wenlock formation possess mineral characters which distinguish them from the types originally described in Shropshire and Herefordshire; but, as the same fossils prevail in all these cases, geological classification is unaffected by such lithological variations. The base of the deposit in Wales often consists, as previously stated, of sandstones or grits, with shales and flagstones, all more or less affected by a slaty cleavage. These have been termed 'Denbigh grits'; but as the sandy beds thicken and thin out rapidly, they are simply to be viewed as local features among the great masses of shale (4^a of the Map)*. In fact, they are nothing more than sediments which were sandy in the portion of a former sea which covered the tracts now constituting Denbighshire, and were cotemporaneously muddy or argillaceous in more eastern meridians. Passing, however, from such varied mineral conditions (for at Marloes Bay in Pembrokeshire the strata of this age are also sandy), it may be affirmed, that usually the Upper Silurian rocks of Wales have been only so far affected by slaty cleavage as to leave them in that disjointed, incoherent state of mudstone (provincially 'rotch'), so useless to the mason and miner, and so cold and profitless to the agriculturist. In all such tracts, where the subdividing limestones are absent, or feebly indicated, it is only by close observation of the imbedded fossils that the formations, so clear and typical in other parts, can be recognized.

When, on the contrary, we follow the same deposits from Wales to the exemplar tracts of Shropshire and Herefordshire, where the Upper Silurian rocks were classified and their order, character, and fossils first described, we find them diversified by interpolated courses of limestone; much calcareous matter being disseminated, both in nodules and in flagstones.

With such additions to the richness of the subsoil, so welcome to the proprietor, the geologist usually discovers a greater abundance of fossil animal remains than in the sterile siliceous or argillaceous strata, cotemporaneously formed, in the western tracts; whilst by

* Although the Denbigh grits are marked in the Map as 4^a, to distinguish them from 4^b, the Woolhope limestone, and 4^c, Wenlock shale, the reader is not to infer that any difference of age is thereby implied; the strata defined by the letters *a*, *b*, *c* being simply lithological varieties of the lower portion of the Wenlock formation usually developed as shale.

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observing the order of superposition, and by tracing the divisionary limestones, he reads off the order of the beds, and chronicles with precision the succession of their respective fossils.

In this way the Upper Silurian rocks are seen to consist, as a whole, of the two formations to which I assigned the names of Wenlock and Ludlow; each of these being subdivided in the manner expressed in this woodcut.

GENERAL ORDER OF THE UPPER SILURIAN ROCKS INCLUDED BETWEEN THE UPPER LLANDOVERY OR MAY HILL SANDSTONE AND THE OLD RED SANDSTONE.

c. Pentamerus rock, in this district often a limestone, but usually a pebbly sandstone (Upper Llandovery or May Hill Sandstone). d^1. Shale, with Lower Wenlock or Woolhope limestone. d^2. Wenlock shale. d^3. Wenlock limestone. e^1. Lower Ludlow. e^2. Middle Ludlow or Aymestry limestone. e^3. Upper Ludlow and Tilestone. *f*. Bottom of Old Red Sandstone.

The inferior member of the Wenlock formation which rests on the Upper Pentamerus rocks, *c*, as seen in Shropshire and parts of Wales, is chiefly a mass of dull, argillaceous, dark grey shale, rarely if ever micaceous, and agreeing with the pale slate before alluded to. Strictly speaking, there is no continuous band of limestone subordinate to the lower shale, d^1, below the escarpment of Wenlock Edge in Shropshire; the rock to which attention is first called being there merely represented, as also in some other tracts, by a few calcareous nodules and bands of sandstone, d^2.

In following these deposits from Shropshire into Herefordshire, the great limestone, d^3, above the shale, d^2, is already found on the banks of the Lugg, west of Aymestry, and not more than ten miles from the Wenlock Edge, to be diminished to a thin irregular stratum, chiefly concretionary. Further to the south-west, and in Radnorshire, the lime disappears entirely amid the mudstones above alluded to; but, to the south of Presteign, an inferior course of limestone is interpolated in the lowest part of the Wenlock shale. This rock, d^1 of the diagram, and which has been alluded to in the last chapter, merits special attention.

Lower Wenlock or Woolhope Limestone.—An examination of the old quarries at Corton, one mile south of Presteign, shows that this limestone is fairly subordinate to a black shale, which rests on the

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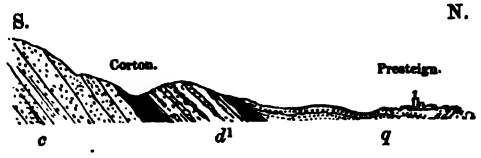
Pentamerus grit and conglomerate before described. This superposition is delineated in the following diagram.

LOWER WENLOCK AT CORTON, NEAR PRESTEIGN.



c. Coarse pebbly grit, known here as 'Corton grit,' with Pentamerus oblongus, &c. d^1. Wenlock shale with Woolhope or Lower Wenlock limestone. *q*. Gravel of the Valley of Presteign.

To the south of Corton lies the large and loftier rock of Nash Scar, formed of the same limestone, which, whether thick-bedded or nodular, has been fused into one subcrystalline mass; the stratified character having been destroyed, and the shale, once associated with the limestone, obliterated, as expressed in this diagram†.

ALTERED LIMESTONE OF NASH SCAR.
(From Sil. Syst. p. 313.)

c. Arches of Woolhope limestone and shale, d^1, followed by d^*, amorphous or altered limestone. *o*. Caverns.

In tracing the strata southwards along this axis, other masses of limestone more or less amorphous are seen near Old Radnor, which, in proportion as they approach the eruptive masses of Stanner and Hanter Rocks, and Worsel Hill, or the highly metamorphosed rock of Old Radnor and Yat Hill, are themselves subcrystalline, and unbedded, with coatings of serpentine upon the surfaces of the joints. On the contrary, in receding westwards from that line of eruption and metamorphism, into the Vale of Radnor, to the south-east of Harpton Court‡, the limestone begins to resume its bedded

† The rocks of Nash Scar and Old Radnor are the only masses of limestone in this region, and as there are no other calcareous rocks worth burning to lime between this district and the sea-coast, they are of high value to the Welsh proprietors; the lime being transported to great distances westward (see Map).

‡ The seat of my esteemed friend the late Sir T. Frankland Lewis, whose successor, Sir George Cornewall Lewis, now Chancellor of the Exchequer, first urged me to put together all my geological records of this region, and form the work afterwards called the 'Silurian System.'

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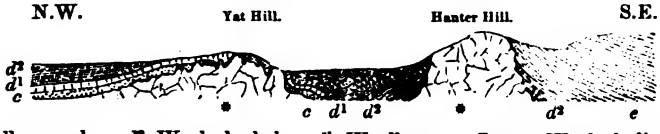
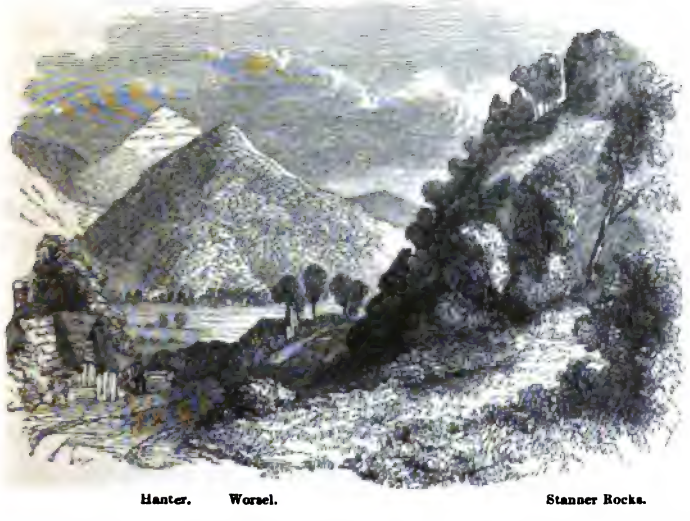
character, resting on the pebbly Pentamerus conglomerates which range by Old Radnor church and Yat Hill. Whilst the following section, taken from one of the coloured sections of the Government Survey, exhibits the syenite and greenstone of Hanter Hill throwing off the Ludlow rocks to the south-east, it is also suggestive of the belief, that another body of igneous rock lies subjacent to the conglomerate and crystalline limestone of Old Radnor and Yat Hill, where the coatings of serpentine and brecciated and altered features of the stratified rocks are, in the eye of the geologist, conclusive evidences in favour of such relations.



e. Ludlow rocks. d^2. Wenlock shale. d^1. Woolhope or Lower Wenlock limestone (partially altered with serpentine faces). *c*. Pentamerus sandstone (Upper Caradoc, *olim*), in parts altered. * Eruptive rocks (syenite, greenstone, and hypersthene rock).

The eruptive rocks of this tract are highly picturesque, and as they offer, in a very small compass, phenomena which characterize large



VIEW FROM STANNER ROCKS (WORSEL WOOD, HANTER HILL, AND HERGEST RIDGE BEING SUCCESSIVELY SEEN IN THE DISTANCE). (From Sil. Syst. p. 311.)

mountain masses, a sketch of them is annexed. The spectator is placed at the south-eastern foot of Stanner Rocks, near Kington,

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which are charged with hypersthene; this mineral, though common in some foreign countries, and abounding at Loch Scavig, in Skye, has hitherto been found in one other British locality only.

The greater expansion of the Lower Wenlock or Woolhope limestone in Radnorshire, as compared with that of the few nodular strata of the same age in Shropshire, must doubtless have been in great measure due to the larger amount of the original calcareous deposit, the nature of which is still visible in the old quarries near Presteign. The amorphous, massive, and crystalline condition, however, of the same rock at Nash Scar and Old Radnor, was, we cannot doubt, caused by the action of heat issuing along a line of fissure, which, emitting the igneous rocks of Stanner, Worsel, and Hanter, fused the strata into huge amorphous masses, and left *films* of serpentine on the faces and joints of the altered limestone.

Nearly all the fossils which have been found in the limestone of this tract, whether by Mr. Edward Davis, who discovered most of them, and specially assisted me in studying them, or subsequently by the Government Geologists, are true Wenlock and Upper Silurian forms.

Some of these, such as the trilobites Bumastus Barriensis, Phacops caudatus, and Encrinurus variolaris, with the shells Leptæna lævigata and Nerita prototypa, large encrinite stems, and several corals, are well-known published fossils of the limestones of Wenlock and Dudley*; and in addition to these, even the Pentamerus Knightii has also been found, which, as will hereafter be stated, is a marked fossil of the overlying Ludlow formation. With these, however, two species of shells have been found which usually belong to a lower horizon,—the Atrypa hemisphærica and Staurocephalus Murchisoni; the former being abundant in the Llandovery rocks, whilst the latter is even a Caradoc or Bala fossil.

Lower Wenlock at Woolhope near Hereford, the Malvern Hills, May Hill, &c.—Let us now consider the character of the lowest calcareous member of the Upper Silurian rocks exhibited in the centre of the most symmetrical valley of elevation in the British Isles, or that of Woolhope in Herefordshire. There, the limestone in question, as seen in the following diagram, forms the exterior coat of a central dome, *c*, in which the summit of the Upper Llandovery rock or May Hill sandstone is barely visible, and from which

* Sil. Syst. p. 313.

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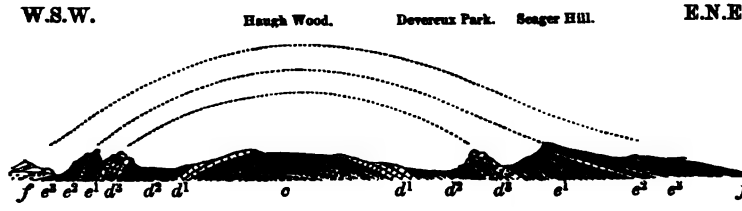
the Woolhope limestone, d^1, dips away on all sides, to pass under the Wenlock shale, d^2, with its chief limestone, d^3; whilst these again plunge under the Ludlow rocks, *e*, and Old Red Sandstone, *f*, as displayed in this diagram. In short, the student has here before

SECTION ACROSS THE ELEVATED VALLEY OF WOOLHOPE. (From Sil. Syst.)



c. Summit of Upper Llandovery rock. d^1. Woolhope or Lower Wenlock limestone and shale. d^2. Wenlock shale. d^3. Wenlock limestone. e^1. Lower Ludlow. e^2. Middle Ludlow, or Aymestry limestone. e^3. Upper Ludlow. *f*. Old Red Sandstone (base of).

him, on either side of the central dome of Haugh Wood, a full exposition of all the Upper Silurian rocks from the base to their summit.

The phenomena of this most remarkable elliptical mass (see Map), insulated and raised up through a great area of overlapping Old Red Sandstone, were first described in the 'Silurian System,' and have since been given in still greater detail by Professor Phillips. The term 'valley of elevation' does not convey an adequate idea of this wonderful geological scene; for within the encircling ridge of Ludlow rocks, e^2, there is one parallel surrounding valley in the Ludlow shale, e^1, and another in the Wenlock shale, d^2, or between the ridge of Wenlock limestone, d^3, and the Woolhope limestone, d^1. Thus, by the elevation of the various strata around a common centre, and by the subsequent excavation of their softer members, the hill or dome of Haugh Wood has been left by natural causes, as if it were a huge, artificial, intrenched camp with two encircling mounds and two circumfluent valleys*.

* One of the most striking features for the consideration of the geologist is, that neither the central dome nor the surrounding ridges, including the outer encircling ring of Ludlow rocks, offer a trace of drifted matter or gravel, nor even any remnants of the various strata, which must, in the process of elevation, have been first bent over in the form represented by the dotted lines, and afterwards demolished. All the debris resulting from the destruction of this once great solid mass has therefore been swept out; the tract being one of clean denudation. Another striking example of a similar phenomenon, and which

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It is on the outside of the inner dome of these symmetrical elevations that the Lower Wenlock zone, as above shown, is most clearly exposed. Having been raised equably on the outward face of the dome of Haugh Wood, the nature of the calcareous deposit can be seen in detail on the sides of the roads, whilst the best limestones, which have been largely opened out since I described the tract, afford numerous fossils unknown when the 'Silurian System' was published.

In ascending order, the beds may be thus described. The top of the central dome of Woolhope, *c*, with its transition beds, is a greenish, earthy, calcareous sandstone, containing the following fossils, as described in the last chapter on the Llandovery Rocks:—Pentamerus lens (Atrypa, Sil. Syst.), Atrypa reticularis (A. affinis, Sil. Syst.), Petraia bina (Turbinolopsis, Sil. Syst.). This course is followed by shale with calcareous, gritty flagstones, containing the large Pentamerus liratus (Atrypa lirata, Sil. Syst.), Foss. 14. f. 3. p. 100, and in the more nodular portions abundance of Leptæna transversalis and Atrypa reticularis. Layers of an impure earthy limestone succeed, containing Strophomena depressa, a species which, though occurring in the Lower Silurian rocks of North Wales, becomes much more abundant in the Wenlock formation.

In the next overlying bands of shale, we pass fairly into the unequivocal Upper Silurian. In these, calcareous matter so increases as to form strong beds of dark, indigo-coloured, argillaceous limestone, which is characterized by cross veins of pink and white calcareous spar. The strongest bed (about 10 feet thick) is a tough, impure, earthy limestone, largely extracted for the roads; and it is again covered by a stratum of purer limestone, followed by shale with an upper bastard limestone. Now, although the whole of the calcareous courses of this subformation have no greater maximum thickness than 30 to 40 feet, still the rock, together with its interpolated beds of sandy shale, is seen to occupy a very great surface on the annexed Map, from its being so equably spread out at a low angle of inclination. Among the chief fossils of this limestone, which I have collected on the spot, are the two trilobites of the following woodcut, viz. Bumastus Barriensis, Foss. 16. f. 2, and

clearly demonstrates the intensely powerful agency of former geological causes, is seen in the heart of the Ludlow promontory, p. 128. The mode of examination of this picturesque tract, which will most interest the traveller, is to enter it by Mordiford, through the only considerable opening by which the waters escape from the interior of the valley, and, mounting to Backbury Camp, walk along the outer ledge of Ludlow rocks, leaving the magnificent Park of Stoke Edith on the left and Devereux Park, both the property of Lady Emily Foley, on the right; and passing along the crest of Seager Hill, thence cross the valley by Woolhope to Fownhope, there rejoining the carriage road. For details, see 'Silurian System,' with enlarged Map, &c., p. 427.

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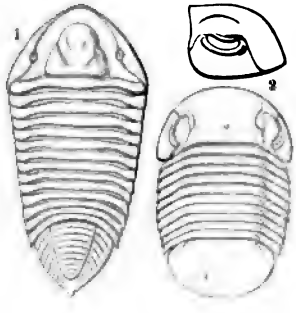
Homalonotus delphinocephalus, f. 1. There are also Phacops caudatus (Asaphus, Sil. Syst.); Cornulites serpularius; Orthoceras annulatum; a species of Phragmoceras; Euomphalus sculptus; Spirifer elevatus; Strophomena imbrex; S. pecten; S. depressa; Leptæna transversalis; Orbicula Forbesi; Atrypa reticularis; Rhynchonella Wilsoni, &c.; and rarely Orthis elegantula.

FOSSILS (16). TRILOBITES OF LOWER WENLOCK OR WOOLHOPE LIMESTONE.



1. Homalonotus delphinocephalus, Green.
2. Bumastus Barriensis, and profile of the head.

These figures are about one-third the natural size.

Here again, as in Radnorshire, we have a great predominance of true Wenlock fossils, and one, the Rhynchonella Wilsoni, which, as we shall presently see, is most abundant in the highest Silurian division, or Ludlow rocks; and thus in their relative position as well as in their fossils, the Woolhope and Radnorshire limestones are identical.

The Silurian formations, which range from the Malvern Hills and the Woolhope district to May and Huntley Hills in Gloucestershire, exhibit the same general order of succession, accompanied, however, by modifications of the lithological and zoological distinctions of the lower member of the Wenlock formation, which it is right to notice. Instead of being the compact, hard, tough, and strong-bedded rock of Woolhope, it becomes, on the western flank of May Hill, a group of nodules and very irregular courses disseminated in shale, simply forming a rather more calcareous base of the Wenlock shale than what is seen under the Wenlock Edge and other places where similar nodules occur. At May Hill, as already shown, there is, indeed, an upward development from masses of Pentamerus sandstone beneath, into a series of interlaminated sandstones and shale, which assume, to a great extent, the fossil characters of the Lower Wenlock. In no portion of Britain, therefore,

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are the two formations of Llandovery rocks and Wenlock shale better linked together than in the Malvern and May Hill region.

This tract, so elaborately described by Professor Phillips, was also carefully studied by Sir Henry De la Beche himself, when the line of demarcation between the Lower and Upper Silurian rocks fixed upon by the Government Surveyors was made the same as that which had been originally suggested in the 'Silurian System*.' On the west flank of the North Malverns, the sandstone with Pentamerus oblongus passes upwards into, and is interlaced with, subcalcareous bands, in which, as before said, these shells are mixed with others essentially Wenlock. After lucidly explaining how such transitions harmonize with well-understood operations in nature, and that in this locality there is no firm and hard boundary between the inferior and superior strata, Professor Phillips thus writes:—"As a general result, it is quite evident, that the successive changes of organic forms, as they are exhibited to us in the successive groups of strata, are not simply dependent on the lapse of time, nor explicable as a series developed in proportion to the time, unless we survey the phenomena over very wide areas, and include in the comparative terms geological periods long enough to neutralize the influence of peculiar physical conditions. These," he truly says, "on account of their local origin, limited area of effect, and recurrence at indifferent periods, have at almost every geographical point, at some epoch or other, broken or mingled the series of organic life†." This is and has long been my belief, as founded on extensive observation.

A limestone subordinate to shale, and bearing precisely the same relations to a subjacent sandstone as that of the localities above cited, occurs on the western and south-eastern flank of the Lower Lickey Hills in Worcestershire. There, the Silurian rocks consist of Pentamerus sandstone, overlapped on its edge by shale, in which are courses of limestone (at Colmer's End), the whole having been thrust up as an irregular dome through the overlying coal-measures and red sandstone. Again, in the adjacent tract near Walsall, and between that town and the Barr Beacon, the same Lower Wenlock or Woolhope limestone, long worked at the Hay Head, dips away from a point of similar sand-

* See Sil. Syst. p. 442 *et seq.*

† See Memoirs of the Geological Survey of Great Britain, vol. ii. p. 75.

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stone*, to pass at a gentle angle of 8° or 10° under the great body of the shale with its calcareous nodules and numerous small fossils; the whole being covered by the thick or chief limestone exhibited in the great quarries of Walsall. The rock contains nearly all the same fossils found at Woolhope, and notably the Bumastus Barriensis, Foss. 16. p. 123, named from the adjacent village, and called by fossil collectors the 'Barr Trilobite;' together with many forms common to the whole formation, including orthoceratites and corals†.

In this way, proofs have been obtained, that a limestone, the real place of which was indicated in several detached districts as being inferior to the great mass of shale, is by its fossils the lowest calcareous member of the Wenlock formation.

Wenlock Shale.—The shale, which is infinitely the largest and most persistent member of the Wenlock formation, occurs both below and above the Woolhope or lower limestone; the latter being absent in many tracts, and in others represented solely by a few small elliptical and round concretions of impure and earthy limestone. The pure shale is well exposed on the banks of the Severn, near Coalbrook Dale and the Iron Bridge, where it is called 'Die Earth‡,' and is thence to be followed all along the escarpment of Wenlock Edge, occupying a broad valley of denudation, called Apes Dale, between that ridge and the Caradoc. In the Malvern and Woolhope districts it is also a mass of finely levigated argillaceous matter, the lower part of which is more calcareous than in Shropshire, and in parts sandy and gritty. Near Malvern, where the shale is in parts highly charged with fossils, particularly the small Brachiopoda figured in Pl. 22, Professor Phillips estimates its thickness at about 640 feet. In some parts of Wales the Wenlock shale is as incoherent as in the adjacent English counties; but in Denbighshire, as before said, it is represented by hard, slaty sandstones and schists.

The prevailing fossils of the Wenlock shale, exclusive of trilobites and corals, which are chiefly species unknown in the lower deposits, are brachiopods of the genera Leptæna, Orthis, Strophomena, Atrypa, and Rhynchonella, mostly of small size. In a general

* Mr. Jukes recently indicated to the Geological Society the existence of this point of sandstone, then called Caradoc. See also his published Survey of this district, Records Geol. Surv. vol. i. pt. 2. p. 240. † See Sil. Syst. p. 488.

‡ So called because this stratum lies beneath all the mining ground.

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way the fossils of this stratum, the chief of which are given in Plates 20 and 22, are the same as those of the overlying limestone. Among them, however, are several common to this deposit and the Lower Silurian rocks, such as Orthis elegantula, so abundant in the slates of Snowdon; Strophomena pecten, S. (Leptæna) depressa, Atrypa marginalis, A. reticularis, and Spirifer plicatellus. Most of these Lower Silurian forms have indeed a much greater vertical range, and pass upwards through the Wenlock high into the Ludlow formation.

The Orthis biloba of Linnæus (Spirifer sinuatus, Sil. Syst.), O. hybrida, and the large, flat Orthis rustica are characteristic shells, as well as Leptæna lævigata, L. transversalis, Pentamerus linguifer, Athyris tumida (Atrypa tenuistriata, Sil. Syst.), Rhynchonella rotundata, R. depressa, R. Stricklandi, R. deflexa, and R. sphærica; and in more western tracts, R. navicula.

Aviculæ, Nuculæ, and some other bivalve shells occur frequently; but few of them are characteristic except the Cardiola interrupta. Of spiral shells, Euomphalus funatus and E. alatus, Pileopsis (Nerita) haliotis, Turbo cirrhosus, Bellerophon Wenlockensis, with B. dilatatus, are the most common. The pteropod molluscs, Theca Forbesi and T. anceps, are not scarce. Certain Orthoceratites, such as O. annulatum, O. filosum, and O. angulatum, are rare; but many of the thin-shelled species, O. subundulatum, O. primævum, and others, abound in these muddy sediments. They are almost the only shells in this formation as it is exhibited in Denbighshire and other parts of N. Wales, and occur there in the greatest abundance. Phragmoceras of one or two species, and certain Lituites, *e.g.* L. articulatus, L. Biddulphi, and occasionally L. giganteus, are conspicuous forms; but the two last-mentioned genera are not commonly met with.

Of trilobites, Encrinurus punctatus and E. variolaris, Calymene Blumenbachii and C. tuberculosa, Phacops caudatus and its variety P. longicaudatus, are characteristic; but one of these, the Calymene Blumenbachii, is known in the rocks of Snowdon. The genera Trinucleus, Asaphus, and Ogygia are never detected even in the lowest portions of the shale; these forms being essentially characteristic of the Lower Silurian rocks. Cornulites serpularius, Pl. 16. f. 6, and other annelides, are sometimes found, as well as stems and portions of encrinites, though the perfect fossils are very rare in the typical region. With respect to corals, it may be stated generally, that they are the same as those of the Wenlock limestone, but fewer in number; the cup corals, Cyathophyllum, Omphyma, &c., Favosites alveolaris, and Stenopora fibrosa, being the most conspicuous. Graptolites priodon (Ludensis, Sil. Syst.),

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which is a most abundant and characteristic fossil of the Wenlock shale, has been already figured as occurring in the Lower Silurian rocks, Foss. 11. f. 3, and Pl. 12. f. 1, 2.

Wenlock Limestone.—The upper member of the formation is a limestone, usually of lighter grey colours than the lower calcareous band already described under the name of Woolhope or Lower Wenlock. Although it is in every respect identical with the well-known limestone of Dudley, I named the rock after the sharp rectilinear ridge of Wenlock (see Map), because its relations to inferior and superior deposits are there better seen than in any other part of the British Isles, as exhibited in this sketch.

WENLOCK EDGE, AS SEEN FROM THE HILLS OF OVERLYING LUDLOW ROCK ON THE S.W. (From Sil. Syst.)

The Valley of Apes Dale, 1, on the extreme left, is in the Wenlock shale. The linear ridge, 2, is the limestone of Wenlock Edge, dipping under the higher ridge, 3, of Ludlow rocks, which also occupy the foreground.

The Wenlock limestone consists of thick-bedded, grey, subcrystalline limestone, very rarely of light pink colour, and in parts argillaceous. In other parts of the Wenlock Edge, the rock is more crystalline, and where varied colours prevail, the matrix being charged with encrinites and corals, it forms a pretty marble, though the slabs are of no great dimensions. The mass is essentially of a concretionary nature, and thus differs much from the flat-bedded Lower Wenlock or Woolhope limestone; being for the most part marked by nodules of small size. Occasionally, however, the concretions are large, and are then locally termed 'ballstones.'

This limestone is underlaid and overlaid by shale of pale grey and greenish tints, copiously charged with small nodules of argil-

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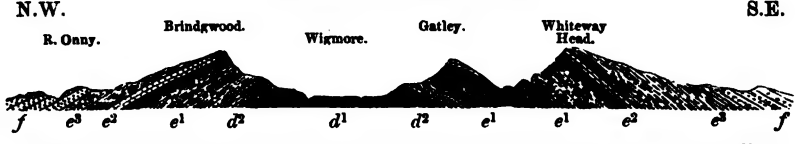
laceous limestone, of very irregular persistence. The 'ballstones' (some of which near Wenlock have a diameter of 80 feet), being more crystalline than the nodules or 'bumbles,' have been quarried out as the best flux for the smelting of iron, and their extraction has left caverns in the quarries, as shown in this woodcut.

OLD QUARRIES IN THE WENLOCK LIMESTONE.

The dark cavities indicate the places from whence the 'ballstones,' or best crystalline limestone, have been extracted. The fossils chiefly occur in the surrounding layers of impure earthy limestone and shale.

But though very thick near Wenlock, this limestone thins out so rapidly in its range to the south-west, that even in the interior of the Ludlow promontory, as displayed in this diagram, it is re-

SECTION ACROSS THE LUDLOW PROMONTORY.
(From Sil. Syst. pl. 31. f. 5.)



d^1. Wenlock shale. d^2. Wenlock limestone. e^1. Lower Ludlow. e^2. Aymestry limestone. e^3. Upper Ludlow. *f*. Old Red Sandstone (bottom beds of).

presented by thin courses made up of small concretions only; and on the banks of the river Lugg, west of Aymestry*, it is merely

* In both of these localities the Wenlock limestone was first traced by my friend the Rev. T. T. Lewis, who liberally gave to me many of the characteristic corals and other fossils figured in the 'Silurian System.'

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represented by a few concretions, varying in size from 2 inches to 2 feet, but still full of beautiful and characteristic corals. Thinning out entirely in Radnorshire, it is scarcely to be recognized throughout the counties of Brecon, Carmarthen, and Pembroke; its place being only marked in the cliffs of Marloes Bay, west of Milford Haven, by some fossils and a small quantity of impure limestone immersed in grey and sandy shale.

In the districts of Malvern, Woolhope, May Hill, and Usk, however, the Wenlock limestone is copiously and instructively developed; and in numberless natural sections and quarries exhibits characters similar to those which it possesses in Shropshire. On the west flank of the Malverns, where in the Ridgeway of Eastnor Park it assumes the same linear outline as at the Wenlock Edge, the limestone is estimated by Professor Phillips to be 280 feet thick. There, in the flexures extending to Ledbury, it is admirably exposed, in connexion with the overlying Ludlow formation (see section, p. 105). At Woolhope it forms the encircling ridge between two parallel valleys, the one in the Wenlock shale, and the other in the Ludlow shale (see section, p. 121). In fact, its ridge-like character is a necessary consequence of the superior hardness of the rock, in relation to the adjacent soft, argillaceous masses.

DUDLEY, FROM THE WREN'S NEST.
(From a Drawing by Lady Murchison, Sil. Syst. p. 480.)

To the north of the town of Dudley, this limestone rises up into domes called the Castle Hill and Wren's Nest, which, with other smaller elevations, have been protruded from beneath the sur-

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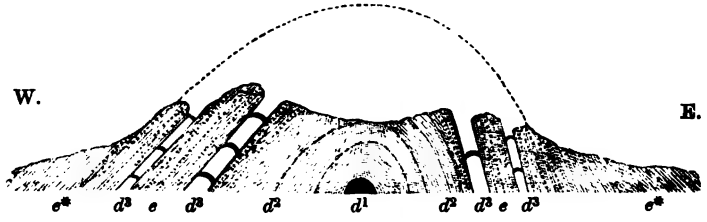
rounding coal strata. The Castle Hill is in the accompanying wood-cut represented to the left hand of the spectator, who is standing on the slopes of the Wren's Nest, and looking southwards over the town of Dudley to the hills of basalt near Rowley.

As the signs of violent igneous action are apparent, both in the subterranean works of this rich mining tract, and in the various outbursts of basaltic or trappean rocks which have been extruded to the surface (Rowley and Pouk Hills, &c.), it is fair to infer that these domes were thrown into their inflated and arched form by subterranean expansion*. The Wren's Nest and Castle Hill thus exhibit on each of their opposite sides two courses of a limestone, which, from its superior quality, has been worked out, first in open quarries and afterwards by deep galleries. The annexed diagram, exhibiting a section through the Wren's Nest, shows how

SECTION ACROSS THE WREN'S NEST.
(From Sil. Syst. p. 484.)



d^1. Lowest Wenlock shale (place of Woolhope limestone?). d^2. Wenlock shale. d^3. Two bands of limestone separated from each other by 'bavin,' e. They are represented by the white spaces, from which the best limestone has been quarried, leaving only arches of support. e^*. Overlying bavin and shale passing up into Ludlow rocks.

the two bands of the best limestone, d^3, have been extracted, leaving only a few arches for support; whilst the other beds, consisting of impure and nodular earthy limestone with much shale, locally called 'bavin,' thus form the framework of the hill. The dotted arch indicates what the dome might have been, if ever entire, whilst the tinted portion of the drawing represents the body of the hill, the upper surface of which, having been hollowed out towards the centre, has obtained for it the name of Wren's Nest. It is, there-

* See the account of the igneous rocks of this district, Sil. Syst. p. 496. First described by Mr. Keir and others, and subjected to experiments by Mr. Gregory Watt, their subterranean relations to the strata have since been ably explained by Mr. Blackwell of Dudley. The descriptions of these and other phenomena connected with the region around Dudley, are given in detail by Mr. J. Beete Jukes, Records of the School of Mines, vol. i. pt. 2. p. 237.

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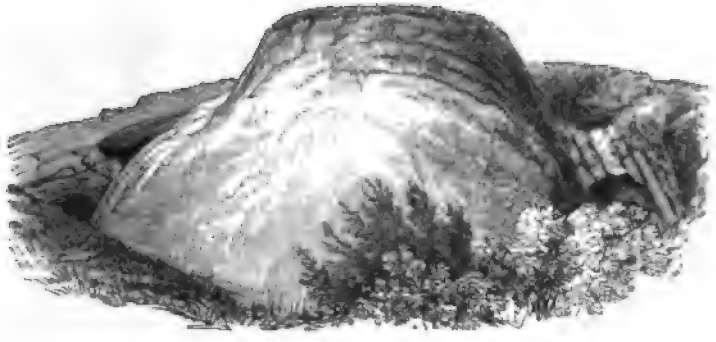
fore, an elevated dome, which may have been produced by lateral pressure, and was probably truncated at its summit during the same period of disturbance and denudation which gave to the mass its peculiar form.

When viewed from below on its southern face, and where necessarily the excavated depression on the summit cannot be seen, the flank of the dome of shale and 'bavin,' whence the limestone has been entirely removed, presents the appearance shown in the diagram.

THE SOUTH END OF THE WREN'S NEST.
(From a Sketch by the Rev. W. Whewell, D.D. Sil. Syst. p. 485.)



The spectator, looking to the north, sees how the limestone strata fold over a central dome of shale.

In the exterior of the nucleus, which also consists of shale, the calcareous matter disappears; but the limestone itself is quite similar in composition and colour, and in its large ballstones, as well as small concretions, to the rock at Wenlock.

At Woolhope in Herefordshire (see p. 121, and woodcut) a similar uprise from the centre has produced, as we have seen, a much grander phenomenon. In the Silurian region the Wenlock formation has seldom a greater thickness than 1000 feet; but in Wales, though void of limestone, it occasionally assumes more than double those dimensions.

The most prominent fossils of the limestone, among which corals abound, have been long known to collectors, who have derived their chief supplies from Dudley and its environs. Those persons who are searching for Wenlock fossils, may, however, be told that their labour will probably be better rewarded by a visit to the northern end of the Wenlock Edge, near Coalbrook Dale, than to Dudley;

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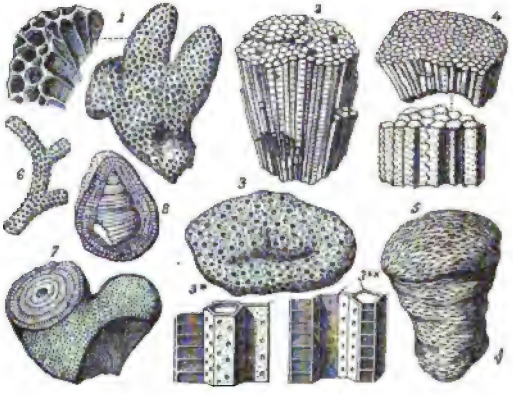
for the corals, encrinites, and shells, along this rich escarpment, are easily detached from the matrix, and the quarries have

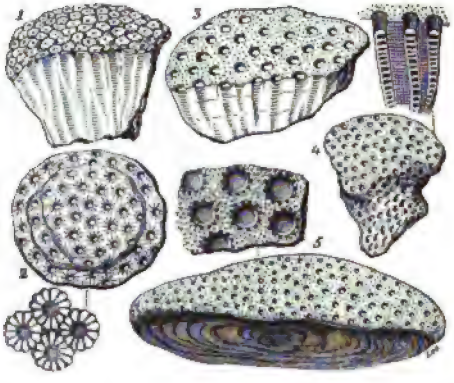
FOSSILS (17). CORALS OF THE WENLOCK LIMESTONE.



1. Favosites cristatus, Blum. 2. F. Gothlandicus, Linn. 3. A variety of this coral; and 3*, 3**, magnified portions of two varieties. 4. Favosites alveolaris, Goldf. (asper, d'Orb.). 5. Alveolites Labechii, Milne-Edw. 6. Favosites oculatus, Goldf.? 7. Stenopora fibrosa, Goldf. 8. S. fibrosa, variety incrusting shells (Alveolites fibrosus, Sil. Syst.).

FOSSILS (18). CORALS OF THE WENLOCK LIMESTONE.

Millepore Corals of the genus Heliolites (Porites, Sil. Syst.), most nearly related to the 'blue coral,' Heliopora cœrulea, Blainv., of the Australian coral reefs.



1. Heliolites tubulatus, Lonsd. 2. H. petalliformis, Lonsd. 3. H. interstinctus, Wahl.; a variety with large tubes. 4, 5. H. interstinctus, Wahl.; ordinary variety.

not yet been exhausted. Benthall Edge, for example, which overhangs the Severn in so picturesque a form, and Gliddon Hill, are excellent localities*. This rock is indeed distinguishable from

* Some of the finest corals originally published in the 'Silurian System' were collected by the Rev. T. T. Lewis, in the gorge of the river Lugg, above Aymestry.

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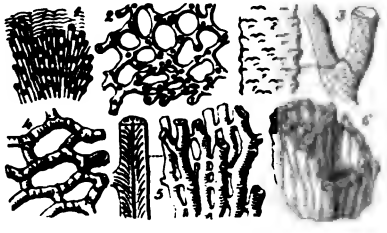
all the inferior strata by the very great abundance of its corals, the profusion of which make it resemble in many places a coral reef. These corals were admirably described for me in the original 'Silurian System' by my valued friend Mr. Lonsdale, who made the first effort to classify them, and to compare them with the determinations of continental naturalists.

In addition to the universal chain-coral, Halysites catenulatus, Foss. 19. f. 6, and the Stenopora fibrosa, Foss. 17. f. 7, which are often met with in the Lower Silurian rocks (see Chap. 9), the fol-

FOSSILS (19). CORALS OF THE WENLOCK LIMESTONE.



lowing species of corals are everywhere typical of the Wenlock limestone:—

Heliolites interstinctus (Porites pyriformis of my old work), Foss. 18. f. 3, 4, 5, both the large- and small-celled varieties; H. tubulatus, f. 1; H. petalliformis, f. 2; Favosites alveolaris, or asper, Foss. 17. f. 4; F. cristatus, f. 1; F. oculatus, f. 6; Cœnites juniperinus, Foss. 19. f. 3; Syringopora bifurcata, f. 4, 5, and its young or creeping form (Aulopora serpens, Sil. Syst.), f. 2; Omphyma turbinata and O. subturbinata, Chap. 10; Alveolites Labechii, Edw.; Cyathophyllum truncatum, Linn., and C. articulatum, Wahl.; Acervularia ananas, Linn.; with many others*.

Of the crinoids, the more perfect only of the forms published in my old work are reproduced in the plates of this volume. Perhaps the large species, Periechocrinus (Actinocrinus) moniliformis, Pl. 13. f. 1, 2, is the most characteristic; it covers large surfaces of the limestone at Dudley, and is found in disjointed fragments in many other localities.

Among the mollusks of this formation, which are figured in Plates 20 to 33, Orthoceratites are very abundant, Orthoceras annulatum

* In the above three woodcuts some of the most frequent corals of the limestone are figured. Here, as in the subsequent chapters on organic remains, the nomenclature differs in a rare instance only, from that of the authors Milne-Edwards and Haime (Polypiers Fossiles). Thus, the genus Heliolites is not divided into three genera, whilst a few of the species are still regarded as being identical with Devonian forms. See M'Coy's Description of the British Paleozoic Fossils in the Geological Museum of the University of Cambridge.

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and O. Brightii being frequent species. Bellerophon dilatatus, B. Wenlockensis, and the singularly beautiful Conularia Sowerbyi, Pl. 25, are characteristic. Among the most frequent spiral shells are five species of Euomphalus, viz. E. carinatus, E. sculptus, E. discors, E. funatus, and E. rugosus (Pls. 24, 25).

Ordinary bivalve shells are less common; but Orthonota cingulata, Avicula reticulata, Pterinea retroflexa and P. planulata, the last figured in Chap. 10, are abundant species. Of Brachiopods, Strophomena euglypha, S. filosa, and especially S. depressa, Pentamerus galeatus, Spirifer plicatellus (S. radiatus and S. interlineatus, Sil. Syst.), S. trapezoidalis, S. crispus, and S. elevatus, Orthis rustica, O. elegantula, and O. hybrida, Leptæna transversalis and L. lævigata*, are all described in the 'Silurian System.' With them are Atrypa reticularis and A. marginalis, besides several plaited Terebratulæ, of which Retzia (Terebr.) cuneata, Pl. 22, and R. Salteri, Davidson, are often plentiful, but the Rhynchonella borealis (Terebratula lacunosa of my old work) is by far the most common species. Rhynchonella Wilsoni and a small variety of R. nucula are also sometimes abundant (see Pl. 22, and woodcuts in Chap. 10).

Trilobites are very common; the most frequent of them is the Calymene Blumenbachii, formerly called the Dudley Locust (Pl. 18), a species which, as we have seen, also occurs deep in the Lower Silurian rocks, and, as we shall presently find, ascends also into the Upper Ludlow.

Other forms of these creatures are also prevalent; a few may be noticed. Encrinurus punctatus and E. variolaris, figured in Chap. 10, are very common in both the limestone and the shale. Phacops Downingiæ is one of the most characteristic trilobites, particularly in the environs of Dudley. The Phacops Stokesii (Calymene macrophthalma of my former work), P. caudatus, Acidaspis Brightii, and Cheirurus bimucronatus (see Pls. 18 & 19), are frequent fossils, and, as before stated, belong also to inferior formations. The Phacops caudatus is especially abundant in the Malvern Hills; whilst the Calymene Blumenbachii is the reigning fossil at Dudley. Bumastus Barriensis and Homalonotus delphinocephalus, which have been cited from the Lower Wenlock or Woolhope limestone, are also found in this rock, the former very frequently. The annelides Cornulites serpularius and Tentaculites ornatus occur on almost every specimen of the limestone at Dudley.

A further acquaintance with the fossils of the Wenlock forma-

* See Plates 20 to 22.

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tion must be obtained by consulting the 10th chapter, as also the descriptive monographs mentioned in the Preface. The object of the present work is not to direct attention to rare forms, but to those which are characteristic of the rocks.

In the above-mentioned districts, the Wenlock limestone passes upwards gradually into a thick mass of pale-coloured shale, undistinguishable from that beneath the solid rock. From the physical relations of this shale, and from its forming usually a part of the same hills as the mass of the Ludlow rock, it is classed with that formation; though the reader must understand, that in reality it is only an intermediate band intimately uniting the Wenlock and Ludlow in the Upper Silurian group, and is almost equally connected with both by structure and fossil contents.

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CHAPTER VII.

UPPER SILURIAN ROCKS—(*continued*).

THE LUDLOW FORMATION, GENERAL CHARACTER OF.—ITS SUBDIVISION IN THE TYPICAL DISTRICTS, INTO LOWER LUDLOW ROCKS, AYMESTRY LIMESTONE, AND UPPER LUDLOW ROCKS.

IN a general sense, the Ludlow rocks of the Silurian region of England and Wales must be simply viewed as a continuation of the argillaceous masses which prevail in the underlying Wenlock formation. Such is more particularly the case in the lower beds of this deposit. The central portion, however, in several tracts consists of an argillaceous dark-grey limestone. The upper member being more sandy and somewhat calcareous, yet retaining in parts much of the 'mudstone' matrix, is in great measure an imperfect, thin-

LUDLOW CASTLE.

(From a Sketch by Lady Harriet Clive, now Baroness Windsor. Sil. Syst. p. 195.)

In this sketch the river Teme is seen to flow in a chasm of the Upper Ludlow Rocks, the strata on which the spectator is supposed to be standing being the same as those on which the Castle is built. The basalt of the Titterstone Clee Hill is in the distance, surrounded by Old Red Sandstone, and covered by carboniferous deposits.

bedded, grey-coloured, earthy building-stone. Occasionally the highest stratum is composed of light-coloured sandy freestones and tilestones, through which the formation graduates lithologically and conformably into the lowest beds of the Old Red or Devonian rocks.

Such is the general order near the town of Ludlow, which stands upon the higher strata of the formation, as shown in this woodcut.

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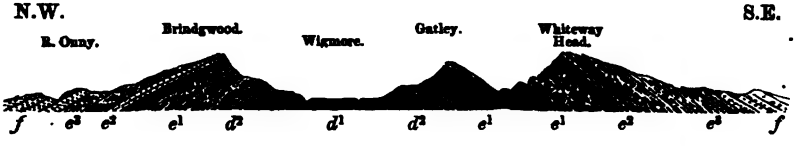
Its central and inferior masses are best seen either in the escarpments of the adjacent hills on the S.W., or in that ridge which for a distance of twenty miles on the N.E. is interposed between the Wenlock Edge and the Old Red Sandstone of Corve Dale and the Clee Hills. The section already given at p. 128, and here repeated, will convey an adequate idea of the succession. (See also Map, and section beneath it.)

SECTION ACROSS THE LUDLOW PROMONTORY.
(From Sil. Syst. pl. 31. f. 5.)



d^1. Wenlock shale. d^2. Wenlock limestone. e^1. Lower Ludlow. e^2. Aymestry limestone. e^3. Upper Ludlow. f. Old Red Sandstone (bottom beds of).

In following the formation from the Ludlow tract on its strike or direction to the S.W., its included limestone, like that of the subjacent deposit, is also soon seen to thin out and disappear. Scarcely has the geologist quitted the north-western corner of Herefordshire, than he finds the central band attenuated to a mere course of calcareous grit, which is entirely lost in Radnorshire. There the Upper Silurian rocks of the mountain of Radnor Forest, which are laid open in the ravine of 'Water break its Neck' and other gullies, expose a gradual succession from the Wenlock through the whole of the Ludlow formation up to the junction beds of the Old Red Sandstone, and with scarcely a trace of limestone. As such also the formation ranges for the most part through Brecon and Carmarthen, the central part being nowhere a workable limestone, and only here and there calcareous, except through the occasional presence of a few testaceous remains. In Marloes Bay, Pembrokeshire, where the Silurian rocks are exposed in the sea-cliffs (see view at the end of this chapter), it is difficult to say more than that sandy calcareous shale and very impure limestone containing Wenlock fossils are surmounted by ferruginous and hard sandstone, rarely calcareous, and in parts a conglomerate.

In the Clyro and Begwm Hills, however, or along the eastern frontier of the Silurian rocks, extending from Kington towards the

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S.W., the Ludlow rocks retain much of their typical characters, and particularly on the banks of the Wye, between Builth and Hay, where I first observed their relation to the Old Red Sandstone. (See Map, and Sil. Syst. p. 312.)

Let us now consider the nature of the different members of the Ludlow formation, where they are most conspicuously characterized by the greatest quantity of fossil remains.

Lower Ludlow Rocks.—These strata, which are, I repeat, simply an upward prolongation of the Wenlock formation, are composed of dark grey shale, rarely micaceous, with small concretions of impure limestone. My chief reason for grouping them with the Ludlow rather than with the Wenlock deposit was, that throughout the typical districts of Shropshire and Herefordshire, these shales occupy the base of the ridges, the harder summits and outward slopes of which are composed of Aymestry limestone and Upper Ludlow rocks.

The clearest and finest examples of such physical features are seen in ascending from the denuded valley of Wigmore, in which the Wenlock shale, d^1, and limestone, d^2, are exposed as in the woodcut, p. 137, and thence by a depression in the Lower Ludlow, e^1, which ranges into the Mary Knoll Dingle and Comus Wood*, until you reach the stronger stony masses of the Aymestry limestone, e^2, and Upper Ludlow rock, e^3.

The inferior strata, e^1, for the most part argillaceous, are often arranged in large spheroidal masses, showing a tendency to concretionary structure, which rapidly exfoliate under the atmosphere and break into shivery fragments. Calcareous nodules, differing only from those of the Wenlock deposit in being usually of a blacker colour, have often been formed round an Orthoceras, Trilobite, or other fossil, as a nucleus.

One of the most prevalent of these organic bodies is our old friend Calymene Blumenbachii, whose acquaintance the collector may have first made in the much lower rocks of Caer Caradoc and Snowdon. (See also Chap. 9.) It is accompanied very frequently by the long-tailed Asaphus, or, as it is now called, Phacops longicaudatus. These

* Milton passed some time in Ludlow Castle, then a border Welsh fortress, and his 'Mask of Comus' was performed in it. Comus Wood is in one of the deep depressions which vary the surface of the Ludlow promontory.

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two may be considered the characteristic trilobites of the formation, though there are several other species; and with them, the Graptolites priodon, or Ludensis*, also a Lower Silurian fossil, occurs abundantly. Nor are the Cardiola interrupta, Pl. 23. f. 12, and Murchisonia Lloydii, Pl. 24. f. 5, less characteristic.

In ascending, the strata become somewhat more sandy, constituting thick, earthy, and very slightly calcareous flagstones, the flaglike separation being due to laminæ of sand. These beds, the 'pendle' of the workmen, were formerly pointed out as being distinguished by containing large orthoceratites. Recently they have attracted much attention at a spot near Leintwardine, and have yielded, to the persevering search of the geologists of Ludlow and its environs, remains of many crustacea and abundance of peculiar starfishes†. Figures of some of the latter are given at p. 141.

These flaglike strata form the support of the Aymestry or Ludlow limestone, from which they are usually separated by soft soapy beds, in parts an imperfect fuller's earth. It is the decomposition of this unctuous fuller's earth (provincially 'Walker's earth') beneath heavy masses of the limestone, which rest upon it, which has occasioned numerous landslips both near Ludlow and in other parts of Herefordshire, one of the most striking of which will presently be mentioned.

The lower shale occupies the escarpments and contiguous valleys of the Ludlow rocks which range from Shropshire by Presteign to Radnor Forest, and also large undulating tracts of the western parts of Shropshire or contiguous parts of Montgomeryshire, such as the Long Mountain, and other tracts around Welshpool and Montgomery (see Map). From the steeps and valleys west of Kington, it extends, together with the upper members of the Ludlow rocks, to the banks of the Wye, and is finely exposed in the noble escarpment at the western end of the Forest of Mynydd Epynt in Brecknockshire. A good idea of the features of that tract is conveyed by a sketch already given, p. 61, where the rounded and soft outline of the hills in the middle ground, as seen from the slaty hills on the west, is due to the soft nature of this deposit.

* Ludensis is the Latin word, signifying "of Ludlow."

† Colonel Colvin of Leintwardine, and Messrs. Lightbody, Cocking, and Marston of Ludlow, have the merit of these last discoveries. Formerly, Mr. Proctor contributed much from the neighbourhood of Leintwardine.

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The same rock is also well developed in the Malvern tract, where Professor Phillips assigns to it a thickness of about 750 feet. (See also section, p. 105.)

In the Woolhope elevation and the group of Usk, or as lying between the Dudley and Sedgeley (Wenlock and Aymestry) limestones in Staffordshire, it is everywhere the same dull, non-micaceous shale, and from its incoherence has, for the most part, been denuded; thus giving rise to a deep valley, which separates the harder parts of the Wenlock and Ludlow rocks from each other.

In the environs of Ludlow, and in many parts of the Silurian region, this inferior member of the Ludlow rocks, whilst containing several forms of trilobites found also in the strata above and below it, is specially characterized by a profusion of straight or curved chambered shells. Such are the Orthoceratites, Lituites, and Phragmoceras, a genus named by my old friend W. Broderip, the eminent naturalist, and which was unknown before the publication of the 'Silurian System.' Orthoceratites abound; not less than eleven species having been figured as characteristic of this rock. But extended researches have shown that, in this case as in many instances of other fossils alluded to, several of these chambered shells occur in much older as well as younger members of the system.

In the rich locality already spoken of, viz. Church Hill, Leintwardine, the usual fossils of this rock have been found associated with starfishes and that singular crustacean the Pterygotus, together with some other forms not yet described.

The Pterygotus belongs to a distinct species from that found in other localities, and is about to be described by Mr. Salter under the name of P. punctatus. It was apparently of great size, perhaps seven or eight feet in length, but its fragments need not be figured here, as a restored figure of the principal species will be given at the end of the chapter.

The starfishes, some of which are here delineated, Fossils (20), are considered to belong to genera, perhaps to families, distinct from any living forms. · One of them, Palæocoma (figs. 3, 4), resembles, indeed, certain living rare forms of starfish (Pteraster) in the great length of the spines, which are, however, longer in the fossil than in the living genus. Palasterina, M'Coy, is more like the Palmipes roseus. Others (Protaster, figs. 1, 2) have the general form of the Ophiuræ or brittle-stars, to which they are allied, but differ in the number and arrangement of the component plates of the skeleton. No less than ten species of star-

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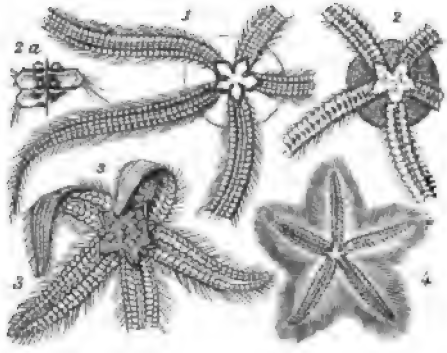
fishes have been already found here, and new forms of great beauty are occasionally discovered.

FOSSILS (20). STARFISHES OF THE LOWER LUDLOW ROCK.

1, 2. Protaster Miltoni, Salter; a form of Ophiuridæ with numerous plates.
2 *a*. Magnified portion of a Protaster.



3. Palæocoma Marstoni, Salter.
4. P. Colvini, id.—These are starfishes allied to Palmipes and Pteraster.

Among the Orthoceratites, the largest, and perhaps the most common, are the Orthoceras Ludense, Pl. 28. f. 1, and O. filosum, Pl. 27. f. 1; these are generally accompanied by a smaller, thin-shelled species, which appears to be the O. subundulatum of Portlock. The others, though often found, are by no means so abundant or characteristic. Of Lituites, the only common species is a very large one, eight or ten inches in diameter—the L. giganteus of Pl. 33. f. 1, 2. The Phragmoceras, above noticed, is a remarkable shell with the mouth or opening contracted into the shape of a key-hole. Some of its forms are flattish, broad, and shaped like a hatchet-head (Pl. 32); whilst others, known as the pear Orthoceratites (Pl. 30), are suddenly swollen into a balloon-like shape above, and end in a tapering point below.

Of lamellibranchiate shells, Cardiola interrupta, Broderip, is the most common (Pl. 23. f. 12); yet the same species, formerly believed to be peculiar to this zone, has also been found in the Caradoc formation! Another bivalve equally characteristic, and as yet known only in Upper Silurian rocks, is the Cardiola striata (Pl. 23. f. 13), and, in company with the chambered shells above noticed, it is to be found in all the fossil-bearing localities of Shropshire and the neighbouring regions. Orthonota rigida, Pl. 23. f. 8, and Pterinea retroflexa, f. 17, are not so common, and the latter is far more frequent in the Upper Ludlow rock.

Many species of fossils have indeed been obtained both in this stratum and the Wenlock formation; especially brachiopodous shells. Among these may be cited the Pentamerus (Atrypa) galeatus, Strophomena depressa and S. euglypha, Leptæna lævigata, Atrypa reticularis, and Rhynchonella (Terebratula) Wilsoni. Scarcely any brachiopod is strictly peculiar to it, unless it be the small but characteristic Lingula lata, Pl. 20. f. 6. In this view, the Lower Ludlow shale might be classed with

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the Wenlock formation; but the other forms of mollusks, above noticed, give to it a distinct character, and entitle it to rank locally as a separate subformation.

Aymestry or Ludlow Limestone.—The want of persistence over wide areas of any mass of solid limestone in the centre of the Ludlow formation has been adverted to. In some parts of South Wales where the calcareous matter is absent, it is difficult to trace even the place of this band in the Ludlow rocks; but in Herefordshire and Shropshire, and again at Sedgeley in Staffordshire (near Dudley), it is a dark-grey limestone, worked pretty extensively for use. Even where the lime is very sparingly distributed, the rock is a highly calcareous flagstone, and may generally be recognized by its well-defined joints and predominant fossils.

This central member of the Ludlow formation was named by me after the beautiful village of Aymestry, where the rock is well laid open, and its relative position as well as fossil contents were elaborately worked out by my friend the Rev. T. T. Lewis*. The clear distinction of this rock from the Wenlock limestone was, indeed, first made by him; so that, whether I look to the informa-

WHITEWAY HEAD. (Escarpment of Aymestry Limestone. Strata dipping to the S.E.) (From Sil. Syst. p. 243. Sketched by the late Rev. W. R. Evans.)

tion I derived from his fieldwork or to the organic remains with which he liberally supplied me, I have every reason to style Mr.

* See Sil. Syst. p. 201.

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Lewis (as I did in the Preface to the first edition) "my most efficient coadjutor in all the region of Siluria."

The Aymestry limestone is a subcrystalline earthy rock, arranged in beds from one to five feet thick; the laminæ of deposit being marked by layers of shells and corals. In the escarpment of the south-western limb of the Ludlow promontory, this rock frequently forms bluff cliffs, the inclined strata of which, as seen in the centre of the preceding woodcut, rest upon the Lower Ludlow shale, and plunge under the Upper Ludlow rock.

When cut into, the rock is of an indigo or bluish-grey colour, in parts mottled by the mixture of white calcareous spar. The quarries, like those in all the harder bands of the Ludlow formation, present, as in the above diagram, natural backs or divisions, usually coated by a dirty yellow or greenish shale. These are the faces of joints more or less vertical, and when open, occasion the rock to separate into rhomboidal masses, which are easily detached if the strata are much inclined. The rock is, therefore, subject to slides or subsidences, particularly where the underlying saponaceous 'Walker's, or fuller's earth' prevails. Examples of these slides may be seen at many spots, but at no locality more instructively

THE PALMER'S CAIRN LANDSLIP.

(From Sil. Syst. p. 248. Drawn by the late Rev. W. R. Evans.)

The woodcut exhibits the slope of the beds and the vertical joints, which in conjunction with the lines of bedding divide the rock into lozenge-shaped blocks.

than at the Palmer's Cairn or Churn Bank, S.W. of Ludlow, represented in the foregoing woodcut. The area there affected exceeds fifty acres.

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This limestone often occupies the summit or capping of the escarpment of Ludlow rocks, as in the ridges of Mary Knoll and Brindgwood Chase west of Ludlow; and in the hills extending from the View Edge and Norton Camp, where it forms a conspicuous band parallel to, and loftier than the Wenlock Edge (see woodcut, p. 137).

At Aymestry, the limestone occupies both banks in the gorge of the river Lugg; but, as above said, it rapidly thins out to the south-west. On the whole it has much less of a concretionary structure than the subjacent Wenlock limestone, and partakes more of the flat-bedded character which is observable in the 'pendle' beneath, and distinguishes, indeed, all parts of the Ludlow formation.

In the old quarries at Aymestry it is conspicuously marked by the lines of cavities whence its numerous corals have been weathered out.

In the Woolhope valley of elevation, the Aymestry rock (see section, p. 121) assumes precisely the same external or physical features as on the flanks of the Ludlow promontory; having from its hardness resisted denudation better than other portions of the deposit. It thus forms the crest of the external and encircling ridge, and is prominent in the hills of Marden, Seager, and Backbury. Although it differs in being a less pure limestone than that near Ludlow, it contains many of the same fossils; even the Pentamerus Knightii, its characteristic shell (Pl. 21. f. 10), having been found in the Woolhope district since the 'Silurian System' was published.

On the outermost western slopes of the Malvern Hills, and on the sides and summits of their northern prolongation, the Abberley Hills, the Aymestry rock, though containing less calcareous matter than in Shropshire, is still the well-defined central portion of the Ludlow formation. In some of these tracts (as near the Hundred House) it might be used for lime, if the Wenlock limestone of such superior quality were not in close proximity. In the districts of May Hill, Usk, &c., this limestone is simply represented by the harder and slightly calcareous central part of the Ludlow rocks.

At Sedgeley, in Staffordshire, the rock becomes once more a useful limestone, in which the predominant Aymestry fossil, Pentamerus Knightii, abounds. There it is known as the 'black limestone,' in contradistinction to that of Dudley, on which, with some intermediate shale or 'bavin,' it reposes*.

The fossils which pervade the Aymestry limestone, in addition to the Pentamerus Knightii, are the Rhynchonella (Terebratula) Wilsoni, Lingula Lewisii, Strophomena euglypha, and large specimens of Atrypa reticularis, Bellerophon dilatatus, Pterinea (Avicula) Sowerbyi, &c.,

* See 'Silurian System,' sections, p. 481 *et seq.* The Rev. T. T. Lewis first called my attention to the fact of the Sedgeley limestone being the equivalent of the Aymestry rock.

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and many of the same shells, corals and trilobites, which are common in the subjacent Wenlock limestone. Indeed, except in the less number of species, and the occurrence of some of the shells more characteristic of the next member (the Upper Ludlow rock), this limestone is not much distinguished by its fossil contents from the Wenlock limestone.

In some tracts, as at Usk, Monmouthshire, the place of this rock is marked only by the shelly courses which near Ludlow form its immediate cover; and, wherever these peculiar beds occur, they are replete with the Rhynchonella (Terebratula) navicula (Pl. 22. f. 12) and the small Leptæna lævigata*. It is this band which forms the base of the Upper Ludlow rock; and it may be well seen in the quarries at Aymestry.

Upper Ludlow Rock.—This is the most diversified, in structure and contents, of the three subdivisions of the highest Silurian formation, and is also remarkable in exhibiting a transition into the next overlying system, the Old Red, or Devonian. Its lowest stratum may be considered the calcareous shelly band, charged with Rhynchonella (Terebratula) navicula, which has just been mentioned as forming the roof of the Aymestry limestone, and which occasionally attains a thickness of 30 or 40 feet. This is surmounted by grey, argillaceous masses, so common throughout the Silurian rocks, and which, from their incoherent nature, easily decompose into mud. Like other Silurian sediments of higher antiquity, this mudstone has a tendency to run into large spheroids, and occasionally contains small concretions of sandy clay, which, being more destructible than the pure argillaceous matrix, weather out in the faces of the escarpments, marking the lines of stratification by small elliptic cavities like swallow-holes.

The chief and distinguishing portion of the Upper Ludlow contains more calcareous matter and sand than the beds immediately beneath. It is, on the whole, a slightly micaceous, thin-bedded stone, of bluish-grey colour within, but weathering externally to a brown, rusty grey, and remarkable for its symmetrical, transverse joints, as exhibited at *a*, *a*, in the following view.

Some strata of this character appear also in the foreground of the vignette, p. 136, which represents the Castle of Ludlow standing on the rock out of which it was built. Though quarried extensively for use, the stones, either when not well selected, or not placed hori-

* Mem. Geol. Surv. vol. ii. pt. 1. pl. 26. fig. 3 (L. lepisma).

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zontally in the wall in the direction of the layers, are very prone to decomposition. This rock is well exhibited near Ledbury also.

UPPER LUDLOW ROCKS AT THE BONE WELL*. (From Sil. Syst. p. 250.)

I have elsewhere compared this member of the Upper Ludlow with the 'Macigno' of Italy, and particularly with those dark greyish portions of the latter which occur between Perugia and Florence. This lithological resemblance of so old a rock to so young a deposit (for the Italian Macigno is no older than the London Clay) is cited to show how similar materials—sand, mud, and calcareous matter, collected on a sea-bottom, often necessarily resemble each other when formed into stone, though originally deposited at such very widely separated periods. In this comparison it is further to be noted, that the 'Macigno,' or *young* Italian rock, is infinitely more hard, compact, and durable, than the very *ancient* stone of Ludlow!†

The surfaces of these Upper Ludlow rocks are occasionally covered by small wavy ridges and furrows, here and there crossed

* This well is so named because bones of mice, frogs, and other small animals are from time to time washed out from the open joints (*a*) of the impending rock. Old Drayton, in his Polyolbion, considered this a great marvel, and converted the bones of frogs into those of fishes:—

"With strange and sundry tales
Of all their wondrous things; and, not the least in Wales,
Of that prodigious spring (him neighbouring as he past)
That *little fishes*' bones continually doth cast."

† See a description of the tertiary Macigno of Italy, in the Memoir 'on the Alps, Apennines, and Carpathians,' Quart. Journ. Geol. Soc. vol. v. p. 280.

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by little, tortuous, raised bands; the former of these are supposed to have resulted from the rippling action of waves, when the sediment was accumulating under a shallow sea, and the latter to have been the traces left by worm-like animals on a sandy and muddy shore during the intervals of the tides.

It is chiefly in this upper portion of the formation that the best defined organic remains are found, often preserving the sharpness of their forms, and the remains of their original shelly coverings.

Here we meet with a profusion of the following fossils:—Chonetes (Leptæna) lata, Pl. 20. f. 8; Orthonota amygdalina, Pl. 23. f. 7; Goniophora cymbæformis, f. 2; Pterinea lineatula, f. 16; P. retroflexa, f. 17; Orbicula rugata, Pl. 20. f. 1, 2; Orthis elegantula (var. orbicularis), f. 9; O. lunata, f. 11; Rhynchonella (Terebratula) nucula, Pl. 22. f. 1, 2; Turbo corallii, Pl. 24. f. 1; T. octavius, f. 4; &c.; and the curved shelly annelide-tube, Serpulites longissimus, Pl. 16. f. 1. The Cornulites serpularius, Pl. 16. f. 8–9, and a small Tentaculite, f. 12, with the minute Beyrichia Klœdeni, Pl. 34. f. 21, are also not uncommon.

Corals are rather scarce; yet Stenopora (Favosites) fibrosa is found frequently encrusting particular species of shells,—Turbo corallii and Murchisonia corallii, Pl. 24. f. 1 & 7, as their names imply, being its favourite habitats. This coral has been figured, p. 132, Foss. 17. f. 8.

Orthoceratites, occasionally of large size, occur; the species being the same as those known also in the Lower Ludlow rock, Pl. 26 *et seq.* Of trilobites, the Phacops caudatus and Encrinurus punctatus, with a rare sample of the Calymene Blumenbachii, reach the summit, but they are not abundant. The most prevalent trilobite is a fine species of the genus Homalonotus (H. Knightii, Pl. 19. f. 7), which may be found throughout the whole range of this formation, from Pembrokeshire to Westmoreland, and is sometimes of very large size.

In the cliffs at Ludlow, the chief body of rock is surmounted by what has been termed the Fucoid bed. This is a greenish-grey, argillaceous sandstone, almost entirely made up of a multitude of small, wavy, cylindrical, stem-like forms, which resemble entangled sea-weeds. In this mass is found, and always in a vertical position, the singular body (Pl. 12. f. 5) named Cophinus dubius. It is generally of an inversely pyramidal shape, and its sides are scored with elegant transverse grooves. I am assured by Messrs. Sowerby and Salter, who have studied it attentively, that it is the impression made by the stems of encrinites, which, rooted and half-buried in the micaceous mud, have produced, by their wavy and somewhat rotatory motion, the beautiful pattern, every line of which answers to one of the projecting bosses or rings of the jointed stem. In fact, these stems are always found lying contiguous to the

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markings. Such bodies, in their slow trailings or gyrations, may have probably left accurate impressions, in consequence of the diffusion of small particles of mica in the mud, the flat plates of which, having been drawn into positions parallel to the line of motion, may have impeded the perfect fusion of the separated portions of the semi-fluid mass after the stem had passed through them.

The highest of the Ludlow rocks is a most interesting division of the younger Silurian group, inasmuch as it is the oldest band in which any remains of fishes and land-plants have been discovered in Britain. The lower layers of this zone, as seen at Ludlow, are finely laminated, earthy, greenish-grey sandstones, containing a few remains of ichthyolites, with several shelly remains characteristic of the formation. It was the central part only of this band, or a gingerbread-coloured layer of a thickness of three or four inches, and dwindling away to a quarter of an inch, which exhibited, when my attention was first directed to it*, a matted mass of bony fragments, for the most part of small size and of very peculiar character. These, with a few remains of shells and crustaceans, including the Pterygotus problematicus, occur in a cement in which varying proportions of carbonate of lime, phosphate of lime, iron, and bitumen are disseminated. Some of the fragments of fish are of a mahogany hue, but others of so brilliant a black, that, when first discovered, they conveyed the impression that the bed was a heap of broken beetles.

The supposed fishes of this stratum, as exhibited in my original work, must now, it seems, be reduced in number. At all events, besides the remarkable Pterygotus, portions of which are figured in Pl. 19. f. 4–6, and which was removed by Agassiz himself to the class of crustaceans, Professor M'Coy has diminished the list of ichthyolite remains by proving that some of the supposed *fish-defences* should also be removed to that group. One of these, to which he has applied the name Leptocheles Murchisoni (see Pl. 19. f. 1, 2), was formerly figured as an Onchus, or

* This course was discovered by my friends and excellent Ludlow coadjutors, the Rev. T. T. Lewis and Dr. Lloyd, the latter now, alas! removed by death. By their assistance, and that of the late Rev. W. R. Evans, I traced this fish-bed in several other parts of the Ludlow promontory. See Sil. Syst. pp. 198, 605. Mr. Evans showed great sagacity and talent in selecting all the forms which might be considered to pertain to fishes. These he affixed to tablets, which I believed to have been deposited with the original Silurian types presented by myself to the Museum of the Geological Society; but unluckily, these unique and precious forms, so carefully drawn by Mr. James De C. Sowerby, and described by Agassiz (see Pl. 35), can now nowhere be found.

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fish-defence*. But although these may be removed from our scanty list of Upper Silurian vertebrata, the ichthyic nature of the specimens figured in Pl. 35. figs. 1–18, is evident. (See Chap. 10.)

The capping of the bone-bed is composed of light-coloured, thin-bedded, slightly micaceous sandstones, in which quarries are opened out near Downton Castle on the Teme;—the Downton Castle stone, Sil. Syst. p. 197. It is traceable also in the vicinity of Malvern.

The uppermost layers of the whole system, and which form a transition into the Old Red Sandstone, consist of thin-bedded flagstones, occasionally reddish, and in certain districts called 'tilestones;' these contain the Lingula cornea, a fossil found in the Ludlow rock, Pl. 34. f. 2, with crustaceans, defences of fishes, and species of the singular genus Pteraspis (Pl. 37. f. 9, 10).

Being compelled in my earlier researches to draw a line of demarcation between the Upper Ludlow formation and the bottom of the overlying Old Red Sandstone, I then included the tilestones in the latter; particularly as in most parts of the region a portion of them decomposes into a red soil; thus affording a clear physical line of demarcation between them and the inferior grey rocks†. The fossils which were then figured as characteristic of such tilestones exhibited little else than species common to the Upper Ludlow rock, and were chiefly obtained from this formation as it ranges through Clun Forest and some parts of S. Wales, where the Bone-bed has not yet been seen. These species and others since discovered have indeed, for eleven years, led me to classify these tilestones with the Silurian rocks, of which they form the natural summit. For, in their range from Shropshire, through Herefordshire, Radnor, Brecon, and Carmarthen, where they are often of red and yellowish colours, they are charged with Orthoceras bul-

* For further illustration of this point, see Quart. Journ. Geol. Soc. Lond. vol. ix. p. 12.

† The reader, who may refer to my original map, must recollect, that it was constructed between the years 1831 and 1836. At that time I coloured such sheets of the Trigonometrical Survey as had been published, and from those and other materials, my own map was constructed. In fact, nearly all the country of Wales to the west of my typical region was then undefined upon accurate maps. Geologists who have had to labour with imperfect topographical assistance in a region which, like this, had been wholly unexplored by miners are not those who will criticise errors of detail, which have been remedied by those who followed me. The classification and chief outlines of my map and sections, as far as they relate to my own Silurian rocks, have indeed, in all essential points, been sanctioned by the numerous geologists who have succeeded me.

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latum, Chonetes (Leptæna) lata, Spirifer elevatus, Orthis lunata, Rhynchonella (Terebratula) nucula, Cucullella ovata, Bellerophon trilobatus, B. expansus, Trochus helicites, Holopella (Turritella) obsoleta, and the minute bivalved crustacean, Beyrichia Klœdeni. (See Pl. 34.) All of these are common fossils of the Upper Ludlow rock; and a few of them descend as low even as the Upper Llandovery rock beneath the Wenlock shale.

If we include the Downton Castle building-stone, this transition-band contains the oldest casts of recognizable terrestrial vegetation yet found in England and Wales*. The specimens hitherto collected are usually small, and little more than carbonized fragments. At the bottom of the detached basin of Old Red Sandstone of Clun Forest in Shropshire, I detected thin layers of matted and broken vegetables (frequently carbonized) in the tilestone or 'firestone' beds of that tract (Sil. Syst. p. 191). Since then, our acquaintance with them has been enlarged, and the Museum in Jermyn Street contains many more specimens from this stratum, among which are the minute globular bodies, Pl. 35. f. 30, called 'Bufonites' in the 'Silurian System,' but which, as will presently be explained (p. 152), are now known to be of vegetable origin.

Though not everywhere divisible into the portions above described, the Upper Ludlow rock maintains, on the whole, a decisive aspect in its range through Shropshire, Hereford, and Radnor into Brecon and Carmarthenshire, until last seen in the cliffs of Marloes Bay, Pembrokeshire. Frequently somewhat calcareous, the deposit is in these districts for the most part a harder and more sandy stone, partaking in a greater degree of the character of the Italian 'Macigno,' as before said, than any other rock of the Silurian system. Sometimes it is even a hard siliceous rock.

On the eastward slopes of Bradnor and Hergest Hills, near Kington, and particularly in the ridges extending thence by Gladestry and Pains Castle to the Trewerne Hills on the Wye, this formation is often admirably exposed in slightly inclined masses replete with fossils. In the escarpment of the Trewerne and Begwm Hills†, and in many other places, it is strikingly exhibited as a grey, shelly, thin-bedded rock,

* In the much older Silurian rocks of Scotland, some traces of the structure of small land-plants have been detected, as will be noticed in the next chapter.

† This was my first Silurian section, 1831, in passing from the *known* Old Red to the then *unknown* Ludlow rocks, Sil. Syst. pp. 5, 312.

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dipping under the bottom beds of the Old Red Sandstone, as in the woodcuts, pp. 121, 128, 137, 151.

Along the outer or western edge of the Malvern Hills, the section of the Upper and Lower Silurian rocks, as illustrated at p. 105, exhibits, in like manner, Upper Ludlow rocks dipping under the Old Red. Descriptions of this subformation, as occurring at many places, from Ledbury northwards, may be consulted both in the 'Silurian System' and in the monograph of Professor Phillips*.

Similar passages upwards, from inferior grey-coloured to superior red rocks, are observable at Usk, and in tracts around that town, where the Ludlow rocks rest upon Wenlock limestone† and are full of the ordinary fossils. This small Silurian oasis in a region of Old Red Sandstone (see Map) is highly interesting, and exhibits on either bank of the river Usk some peculiarities of mineral structure connecting the eastern and western tracts of the Silurian region.

In Brecknockshire, to the south of Builth, the Ludlow rocks, surmounting a noble escarpment of the lower member of the Upper Silurian on the right bank of the Wye, but in which no limestone occurs, exhibit a fine upward development, as they pass under the Old Red Sandstone in the wilds of Mynydd Epynt (see the long vignette, p. 61, and

BRECON ANTICLINAL OF LUDLOW ROCKS, THROWING OFF OLD RED SANDSTONE.
(From Sil. Syst. p. 211.)

e^1. Lower Ludlow. e^2. Middle Ludlow with a calcareous band representing the Aymestry limestone. e^3. Upper Ludlow. *f*. Old Red (lowest beds).

Chapter 11). There the Upper Ludlow rises from beneath the Old Red, in a rapid anticlinal flexure at Alt-fawr and Corn-y-fan, as here represented; the central and lower members of the formation forming the underlying, arched, untinted strata, e^1.

Thence into Carmarthenshire, the junction of the Ludlow rocks with the Old Red Sandstone is well laid open in numerous places, especially in the narrow valley of Cwm Dwr, between Trecastle and Llandovery, where the tilestones, on which Horeb Chapel stands, are full of the casts of shells, among which are characteristic forms, such as the Trochus helicites, Turbo Williamsi, Bellerophon trilobatus, and many others.

The banks of the river Sawdde, in Carmarthenshire, east of Llangadock, also expose a good junction of these highly micaceous Upper Silu-

* Mem. Geol. Surv. Great Brit. vol. ii. part 1. † Sil. Syst. p. 408.

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rian flagstones with overlying Old Red marl; the whole at very high angles of inclination. Thence, in its range to the mouth of the Towy, the Upper Ludlow becomes a compact hard sandstone, everywhere surmounted by Old Red*.

In Pembrokeshire, similar junctions with the Old Red Sandstone are seen near Tavern Spite, Narberth, at Freshwater East and West, and in Marloes Bay. In all these places, strata of dull greenish-grey argillaceous sandstone, minutely micaceous, differing from the type of the Upper Ludlow of Shropshire in being harder and thicker-bedded, repose on rocks with Upper Silurian fossils, and plunge under red and green strata (the 'red rab' of Pembroke), or bottom beds of the Old Red Sandstone.

In the valley of Woolhope, the same succession is very apparent all round the external rim of that remarkable elliptical elevation (see diagram, p. 121). In nearly all parts of that boundary, the Upper Ludlow is well exposed in its characteristic lithological condition, and is copiously charged with its prevalent fossils, Chonetes (Leptæna) lata, &c., Pl. 20 *et seq.* Its upper beds even contain, in one or two spots, the remains of fishes.

At Hagley Park, distant only two miles from the north-western end of the Woolhope ellipse, and four miles east of Hereford, the uppermost beds of the Ludlow formation have been exposed from beneath their cover of red clay and marl; and there the thin bed, containing fish-bones and the crustacean Pterygotus, was found by Mr. H. Strickland to be just in the same relative position as at Ludlow†. This spot marks a minor undulation, or dome of Ludlow rock, the surface of which only is visible: a much greater mass of the formation has been protruded in the adjacent hill of Shucknall, as formerly described (Sil. Syst.). At Hagley Park, the fish-bed, scarcely exceeding an inch in thickness, lies between strata of brownish and yellowish sandstone (the Downton Castle stone) and a grey micaceous shale full of Upper Ludlow fossils. The fish-remains are chiefly those of the minute shagreen scales (Pl. 35. f. 18), the fish-defences Onchus Murchisoni and O. tenuistriatus (figs. 13–17), with Coprolites (figs. 21–28). In the sandy beds above these there are the remains of carbonized vegetables, and among them Mr. Strickland detected some of the minute globular bodies mentioned before, which Dr. Hooker has ascertained to be seed-vessels belonging to the natural order Lycopodiaceæ. Similar vegetable traces have been observed at various places around the external rim of the Woolhope ellipse, as near Stoke Edith, &c.

Since the publication of the first edition of this work, the bone-bed has been discovered at Brockhill, by the Rev. F. Dyson, and by Mr.

* See woodcuts, pp. 57, 58.

† I visited the spot since the discovery, in company with Mr. Strickland. See his descriptions of these beds in the S. of Herefordshire and in Gloucestershire. Quart. Journ. Geol. Soc. Lond. vol. viii. p. 381, and ib. vol. ix. p. 8.

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Salter at Hales End, both near Malvern. It is a calcareous layer, full of common Ludlow shells, and overlaid by Downton sandstone.

Again, in the southernmost prolongation of the Silurian group of May Hill and Huntley Hill, where I formerly described the whole Silurian series as reduced to one thin mass of Ludlow rock, having the Old Red Sandstone on one side, and the New Red on the other, my lamented friend Mr. Hugh Strickland detected one of these thin fish-bone layers in precisely the same position as at Ludlow.

In the arched or dome-shaped masses of Upper Silurian rocks, which rise out from beneath the Old Red Sandstone at Pyrton Passage on the Severn, Professor Phillips has also noted the remains of small fish-bones in the Upper Ludlow rocks*.

The persistence of the uppermost band of the Ludlow rock, with the oldest land-plants and fishes yet recognized in Britain, and certain shells, at considerable distances from the tract in which it was first described, is truly remarkable, and shows the value of close and minute researches over extensive areas†.

Since the publication of the first edition of this work, discoveries have been made of new forms of animal remains in the upper layers of the Ludlow rocks and the tilestone strata into which they pass upwards, which merit a special notice.

Recognizing the original bone-bed of the Ludlow rock on the face of Bradnor Hill near Kington, Mr. Richard Banks has shown that it is there overlaid first by liver-coloured strata containing the Chonetes (Leptæna) lata, Orthonota amygdalina, &c. A bed charged with Trochus helicites and Lingula cornea then occurs, followed by other strata of somewhat different mineral character, containing the remains of fishes and their coprolites, with the peculiar crustacean Pterygotus, &c.‡

* Mem. Geol. Surv. of Great Brit. vol. ii. part 1. The succession of the Silurian rocks in the dislocated tract of Tortworth, to the S.E. of Pyrton Passage, is described in detail in the 'Silurian System,' p. 99.

† Another example of the ascending order from the mass of the Upper Ludlow rock through the chief bone-bed into the overlying Downton Castle building-stone, has recently been detected by Mr. Alfred Marston, near Norton, on the road to Onibury, where the fish-bed, six inches thick, is surmounted by a thin course charged with Pterygoti, and covered by argillaceous layers (replete with the Trochus helicites and Beyrichia Klœdeni), which form the base of the Downton Castle sandstone. Mr. Lightbody has observed a similar succession at the north side of Whitcliffe Coppice, near Ludlow.

‡ Quart. Journ. Geol. Soc. vol. xii. p. 93. That these Kington rocks contain Coprolites similar to those described from Ludlow has been determined by

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The lowest of these overlying beds, as well exposed in quarries towards the summit of Bradnor Hill, north of Kington, is a greyish and yellowish band, containing the Trochus helicites, together with a species of Modiolopsis, and the Beyrichia, fossils which have been considered characteristic of the Upper Ludlow rock*. This is followed by a thin layer of flaglike sandstone with many species of Onchus and the Lingula cornea. This thin layer, and another which is charged with fragments of Pterygoti and two species of ichthyolites—Pteraspis, are surmounted by the bluish or light grey, hard building-stone of Kington. This again is covered by less massive beds (also charged with the same crustaceans and fishes, together with fragments of carbonized plants) that graduate insensibly into more micaceous and thin-splitting layers, formerly used as tiles. Now, all these strata constitute the regular summit of the range of the Kington Hills, the soil of which is nowhere red; though, in following them in their gradual inclination to the south-east, into the lower grounds of Herefordshire, on the banks of the river Arrow, they are seen to be covered by red marls and sandstone.

In the environs of Ludlow, remains of fishes and crustaceans in beds at a higher level than the original bone-bed have also been detected, chiefly through the close researches of Mr. Lightbody. In the railroad cutting to the north-east of Ludlow, a small insulated portion of an olive or grey-coloured shale was exposed. It is faulted on the north-west against old red sandstone, and is conformably surmounted on the south-east by red marls, &c. The lowest visible layer at this spot is a finely levigated, liver-coloured, and greyish rock in which certain ichthyolites and fossils occur; and this passes upwards into an overlying reddish-brown, micaceous sandstone, which in its turn graduates into red shale or marl. It is manifest, therefore, that this member is distinct from and superior to the first-described Ludlow bone-bed (Sil. Syst. p. 198); since that stratum is fairly overlaid by grey rocks and the Downton Castle building-stone. In the beds at the railroad there have been found fragments of the genus Plectrodus and the Onchus Mur-

the analysis of Dr. Hofmann, of the Government School of Mines, who has found that these bodies consist chiefly of phosphate of lime with small quantities of phosphate of magnesia, silicate of alumina, sulphate of lime, with traces of sesquioxide of iron, oxide of manganese, chloride of sodium, and organic matter. There are also in these rocks, extending from Kington to the south-west, perfectly round nodules chiefly of iron pyrites with a siliceous matrix.

* In examining the beds at Kington in company with Prof. Ramsay and Mr. Aveline, I was much gratified and interested in looking through the valuable collection made by Mr. Banks of the fossils of the Ludlow rocks, and of the beds forming their natural capping. The Ludlow bone-beds discovered by Mr. Lightbody were also visited by my associates and self, together with Mr. Salter, who identified most of the fossils *in situ*, and who found that the remarkable crustaceans (Pterygoti) which occur in this stratum were of several distinct species. (A Decade, descriptive of these fossils, for the Memoirs of the Geological Survey is in preparation.)

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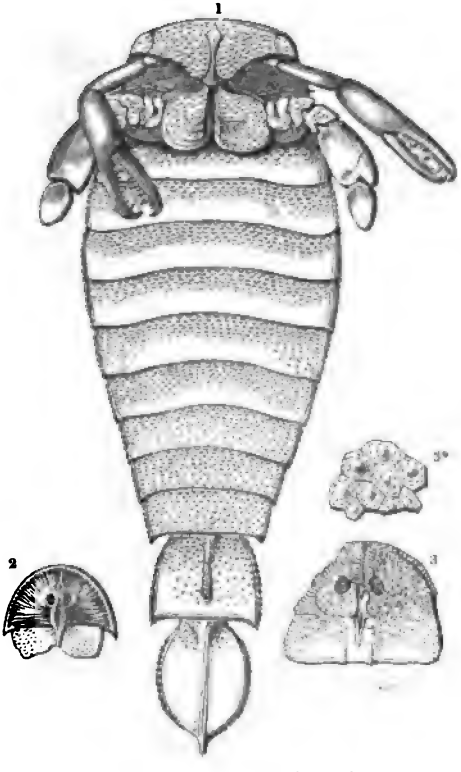
chisoni, both of them species found in the lower bone-bed, and also the Lingula cornea and Beyrichia Klœdeni, Pl. 34. f. 2 & 21. On the other hand, the following species here found are unknown in any inferior stratum, viz. Cephalaspis ornatus, Egerton; a new genus, Auchenaspis Salteri†, Eg.; Pterygotus Anglicus, Ag.; Eurypterus pygmæus, Salter.

FOSSILS (21). CRUSTACEA AND FISHES FROM THE TRANSITION BEDS, LUDLOW.



1. Pterygotus Anglicus, Ag., restored (about $\frac{1}{20}$th of the natural size).
2. Auchenaspis Salteri, Eg.
3. Cephalaspis? ornatus, Eg. (Half natural size.)
3*. Portion of fig. 3, magnified.

A restored figure is here given of the gigantic crustacean, Pterygotus Anglicus, whose pincers and other parts have been collected at this spot. Mr. Salter concludes that this giant of the Crustacea measured not less than seven or eight feet in length, and had a proportionate breadth and thickness. Some further details of its structure will be given in Chap. 10.

On the right bank of the river Teme, opposite Ludlow, a clearer ascending succession of strata has been traced, notwithstanding a heavy cover of drift and gravel, and chiefly by observing the strata which appear when the river is very low. Thus, the rocks containing the

† The Auchenaspis differs from the Cephalaspis in having the buckler truncated behind, and the nape of the neck covered by two wide square plates with granular surfaces; a character not found in the broad lunate heads of fishes so common in the Old Red Sandstone of Scotland and Herefordshire.

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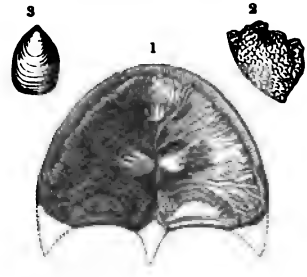
original bone-bed are observed to slope gently down to the south-east, and to pass under light-coloured flagstones, which at the Corn Mill near Ludford are overlaid by micaceous brownish sandstone. These again are followed by reddish marls with greenish minute concretions. Whether the same fish-bed which is observable at the Railroad may not be detected at this point is uncertain, as the series is irregularly traceable only *. But above all these strata, both grey and red, there occurs a band of light grey micaceous sandstone or grit with carbonaceous markings and seed-vessels of cryptogamic plants, and in it Mr. Lightbody has detected remains of fishes and other fossils. Among these we again find the Plectrodus mirabilis, Onchus Murchisoni, and Lingula cornea of the

FOSSILS (22) OF THE UPPERMOST BONE-BED, NEAR LUDLOW.



1. Cephalaspis Murchisoni, Eg. (Less than half of the natural size.)

2. Pterygotus, fragment of foot.
3. Lingula cornea, Sil. Syst.

lower bone-bed, though the Trochus helicites of that horizon is no longer detected. It may, therefore, be naturally suggested, that this band constitutes the last link in the chain of Silurian life.

In this rock there is, indeed, a form of fish, not yet seen in the inferior courses, to which Sir P. Egerton has assigned the name of Cephalaspis Murchisoni (Quart. Journ. Geol. Soc. 1857). It is represented in the preceding woodcut; and, differing, as it does, in a marked manner, by the truncated, not arched, posterior margin, from the Cephalaspis Lyellii of the Old Red Sandstone, this species may be considered as characteristic of a bed which indicates a true passage from the summit of the Silurian rocks into the Devonian rocks or Old Red Sandstone. In the copious development of red marls and thick-bedded sandstones which follow, the fossils that characterize the inferior strata are no longer detected.

The tilestones are visible all along the eastern frontier of the Silurian rocks (particularly from Kington to the Trewerne Hills on the Wye), and scarcely exceed forty or fifty feet of maximum thickness, including both their thick and thin strata, and even some reddish marl and micaceous sandstones. They constitute, therefore,

* It is manifest that faults must abound near the apex of the elevated Ludlow promontory, and that dislocations similar to that which occurs at the Railroad may be frequent.

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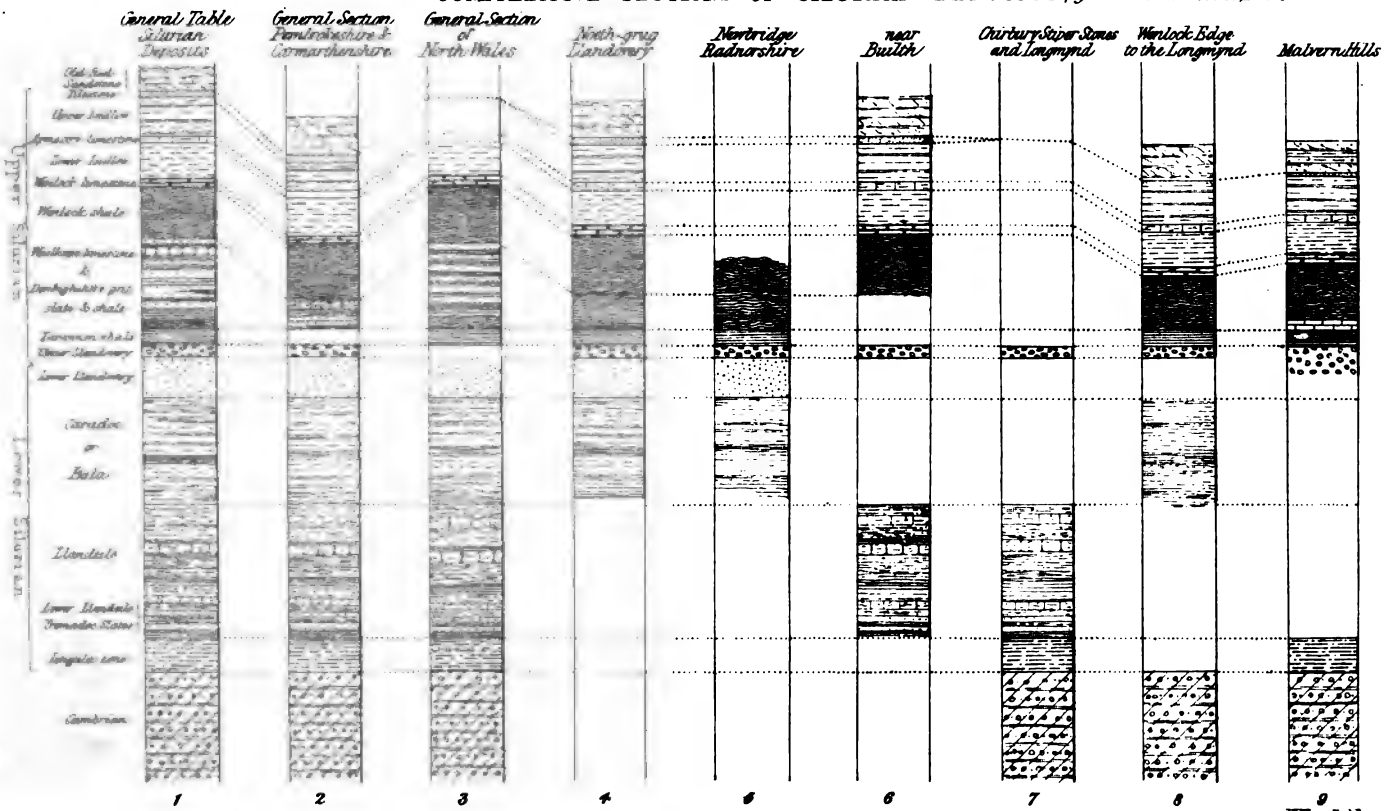

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both lithologically and zoologically, a term of true transition, and cannot be arbitrarily classed as a whole either with Silurian or Devonian. It is, however, manifest from its organic remains that the lowest of the bone-beds is really part and parcel of the Ludlow rock*.

In the next chapter it will, indeed, be seen, that large and peculiar species of crustaceans (Pterygoti) also specially characterize the very uppermost beds of the Silurian rocks of Scotland, or the black slaty shale of Lanarkshire, which clearly underlies every stratum to which the term Old Red Sandstone has been applied. Again, as will afterwards be shown, the same term in the series of the paleozoic rocks of Russia, viz. grey and calcareous strata underlying all the Devonian rocks, is characterized by crustaceans of the family of Eurypteridæ; whilst both in Scotland and Russia these crustaceans are associated with the Lingula cornea, an unmistakeable shell of the Upper Ludlow rock.

The formations and subdivisions of the Silurian rocks of the region illustrated in the Map having now been described in the greatest detail compatible with the limits of this work, the reader is referred to the accompanying lithographed Table of comparison, that he may recognize at one view the varied developments of the strata in different tracts of Wales and the adjacent English counties.

The first of the vertical columns in this Table represents a more complete series than can be seen in any one consecutive natural section. It is a union of all the known strata, as derived from various localities. A near approach, however, to this complete sequence of beds is observable in South Wales, as expressed in the second column, which country, including Llandovery, No. 4, together with Shropshire, Herefordshire, and the border Welsh tracts of Montgomery and Radnor, Nos. 5, 6, 7, 8, & 9, constituted the original Silurian region. By observing this comparative view, we mark the attenuation, in one or more districts, of deposits which are

* Mr. D. Page, in his able Manual, has placed the original Ludlow bone-bed at the base of the Old Red Sandstone. His ground for this classification is, that fossil fishes here first appear. But I contend that the presence of thePlectrodus mirabilis and Onchus Murchisoni (Sil. Syst.) in the lowest of these bone-beds affords no reason for separating it from the Ludlow rocks; seeing that this very band is filled with marine shells unequivocally of Silurian age, many of which are found low down in that system.

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expanded and interpolated in others; also that certain bands well exposed in limited areas are wholly omitted in other tracts. The inquirer has thus before him the condensed result of the long and laborious researches of the Geological Survey in unravelling the highly diversified conditions of the substrata in Wales and Siluria.

In viewing this Table it is to be recollected, that in the column No. 8, the ascending order might have been continued through the Ludlow rocks up to the Old Red Sandstone; inasmuch as that succession is everywhere visible to the S.E. of the Wenlock Edge. By combining such an ascending section as is seen in No. 1 (and which is everywhere apparent along the Silurian frontier) with the section from the Longmynd to the N.W. (No. 7), in which the lower divisions are fully developed, *the geologist has before him, in Shropshire only, the whole Silurian system from its base to its summit,* with the exception of the hiatus occasioned by the absence of a portion of the Llandovery Rocks explained at p. 99. In this same limited tract, he also sees the most copious development of the Cambrian rocks known in Great Britain (the Longmynd); and finds, in short, nearly all the strata which by great undulations are spread over the Principality of Wales and various English counties!

In the succeeding chapters, numerous allusions are, indeed, made to great dislocations or faults, a complete acquaintance with which can alone be obtained by consulting the maps and horizontal sections of the Geological Survey. Reverting for a moment to such phenomena, the reader has only to refer to the section at p. 99, to see that, by the compound fractures of the crust in even the typical Silurian tract of Shropshire, the very oldest known sediments of Britain are brought into contact with various overlying rocks. In that diagram, reduced from the Survey sections, we see, indeed, how different Upper Silurian rocks are broken up and forced in between an upper member of the Lower Silurian and the deep-seated Cambrian rocks of the Longmynd. And yet the geologist has only to follow the undulations of the Lower Silurian strata into Montgomeryshire (see p. 62) to find the regular consecutive order re-established between those rocks and the overlying strata; whilst in Shropshire, Herefordshire, and South Wales the Upper Silurian rocks equally follow a clear ascending order.

In terminating this sketch of the remarkable British Silurian

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region exhibited in the Map, and leaving the further description of the fossils for separate chapters, the following vignette is introduced, to represent at a glance the only section on the sea-coast where a large proportion of the Silurian rocks is seen to dip under the Old Red Sandstone. At the eastern end of St. Bride's Bay, in Pembrokeshire, the Lower Silurian rocks, much dislocated, and associated with those bands of trap which form a striking outline in the Skomer Isles, plunge rapidly to the south-east, and sink under the strata of the mainland; the latter consist chiefly of quartzose and schistose rocks, such as are well seen in Wooltack Pack, associated with much igneous matter.

One of the highest of these broken bands (*c*), representing the upper Llandovery rock, forms the foreground of Marloes Bay; the

SILURIAN ROCKS OF MARLOES BAY, DIPPING UNDER THE OLD RED SANDSTONE OF HOOK POINT, PEMBROKESHIRE. (From Sil. Syst. p. 392.)

chief cliffs in the landscape being composed of schists and sandstones of considerable dimensions, all highly inclined to the south-east, as expressed in the preceding vignette. The upper portion of these strata (*d*), comprising a few courses of impure limestone, contains the fossils of the Wenlock formation, and is covered by some equivalents of the Ludlow strata, in the condition of hard, siliceous grey rocks; the whole being overlaid in the distance by the Old Red Sandstone (*e*) of Hook Point*.

* In the corner of the accompanying Map, attention is directed to an enlarged portion of this tract, in which the powerful dislocations to which the strata have been subjected are marked.

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CHAPTER VIII.

SILURIAN ROCKS OF BRITAIN BEYOND THE TYPICAL REGION OF ENGLAND AND WALES; NAMELY, IN CORNWALL, THE NORTH-WEST OF ENGLAND, SCOTLAND, AND IRELAND.

THOUGH occupying large spaces in other parts of the British Isles, the Silurian rocks, as separated into formations and characterized by fossils, are nowhere so clearly defined as in the typical portion of the region of which we have taken leave. In no other tract of the United Kingdom have geologists been able to show so clearly the relations of the lowest fossiliferous or protozoic rocks to others beneath them which exhibit scarcely any signs of former life; nor so clear an ascending order from the Silurian into the next overlying deposit, the Old Red Sandstone or Devonian rocks.

In Cornwall, for example, the discovery within only the last few years of certain fossils has proved that some of the quartzose sandstones forming its southern headlands are Lower Silurian. The fossiliferous sandstone in question passing to the south of the Dodman, and coming out to view in Gorran Haven, contains several species of Orthidæ as well as trilobites highly characteristic of that division*.

There, however, no one can show an unbroken descending sequence beneath those beds, nor an ascending order from them to the contiguous and younger deposits of Devonian age; and as large portions of the strata of Cornwall have been highly altered and mineralized, so also is this southern tract much dislocated. In such a region, therefore, we cannot expect to meet with proofs of succession. It is sufficient to state, that the band of siliceous grits and quartzites in the south of Cornwall, which I had termed Silurian in 1846, presents much of the character and aspect of

* These fossils were collected by Mr. Peach, and, from their inspection and a visit to their chief localities in 1846, I pronounced the rocks in which they occur to be Lower Silurian (Trans. Roy. Geol. Soc. Cornwall, 1846, p. 317), and, as such, they were inserted in a new edition of my Geological Map of England and Wales, published by the Society for the Diffusion of Useful Knowledge.

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the opposite rocks of Brittany, which the French geologists have mapped and described as Lower Silurian (see Chapter 16). This is precisely one of those broken and insulated tracts of older sedimentary rocks, where the geologist has no other test by which he can recognize age than their imbedded organic remains.

Professor Sedgwick, who has visited the localities since I described them, shows, indeed, that these strata are *inverted*; the Lower Silurian (which he calls Cambrian) *overlying* the Devonian or Old Red rocks. At the same time, the chief fossils defined by Sowerby and M'Coy* consist of the simple plaited Orthidæ so very common in the Lower Silurian rocks, viz. Orthis calligramma, O. flabellulum?, O. elegantula, and O. testudinaria; Strophomena grandis, Pl. 5, 6, *et seq.*; and the trilobites Homalonotus bisulcatus, Calymene duplicata?, and Phacops apiculatus. These are all true Lower Silurian types of Caradoc age.

In the north-western and mountainous part of England, the Silurian rocks appear in great force in the counties of Westmoreland and Cumberland with the adjacent tracts of Lancashire and Yorkshire. Though some of the members there assume a lithological aspect different from what they maintain in the Silurian and Welsh region, they have been clearly paralleled by several geologists with those original types. Professor Sedgwick, who has most studied the Lake region (which I have also traversed on three occasions for purposes of general comparison), and who has described it in a series of valuable memoirs, has grouped the lowest fossiliferous limestones, or those of Coniston, in his Cambrian rocks, though during several years he identified them by means of the published fossils with the Lower Silurian and even with its upper portion.

In truth, the region of Siluria, as geologists now admit, afforded the key by which the fossiliferous strata in the north-western tracts of England were brought into order and had their proper places assigned to them. For, in Cumberland, where the lowest members of this primeval series rise up into the lofty mountains of Skiddaw and Saddleback, the inferior masses of crystallized schists, which pass downwards into fine, glossy, chiastolite slates, have been too

* See Quart. Journ. Geol. Soc. Lond. vol. viii. p. 13.

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much metamorphosed by eruptive, granitic rocks, to allow us to hope for the detection in them of a very regular order, still less of organic remains. These beds are followed by green slates and porphyries, in which no fossils have yet been found, owing, as it is believed, to the great abundance of igneous matter. In vain, therefore, in such a country, does the geologist seek for the equivalents of the bottom rocks, described in the earlier chapters as overlaid conformably by strata with Lingulæ and trilobites. Nowhere in the Lake region have the repeated labours of geologists or fossil collectors, not even of that close searcher John Ruthven, detected the lower band—or 'Lingula flags'—of North Wales, unless it be represented, as Professor Sedgwick thinks probable, by the few graptolites and fucoids of the Skiddaw slate. With the rare exception of sea-weeds and a zoophyte, not a trace of a fossil has been detected in the thousands of feet of strata, which, with interpolated igneous matter, intervene between the slates of Skiddaw and the Coniston limestone, with its overlying flagstones, &c. At that zone only do we begin to find anything like a fauna; and judging from the organic remains, it must be admitted to be a representative of the massive Caradoc or Bala of the Lower Silurian rocks. For, among the fossils, the same species of simple plaited Orthidæ, of trilobites and corals, are again met with which characterize the limestones of Bala or the shelly sandstones of Caer Caradoc in Shropshire.

From physical data, and the great thickness of the strata, we may hypothetically admit, that Professor Sedgwick is right in assigning to the schists of Skiddaw (in which graptolites and fucoids alone have been found) as high an antiquity as the lowest fossiliferous beds of North Wales and Shropshire. But all we can safely say is, that, reasoning from the graptolites, the whole is a Lower Silurian series, which in its inferior parts is metamorphosed and obscured by igneous eruptions, and exhibits no decided representatives either of the Llandeilo formation or the Lingula flags, still less of the Longmynd or bottom rocks of the typical region.

In proceeding, however, to the south and south-east from the more mountainous and crystalline part of this north-western tract of England, the Lower Silurian rocks are seen to be succeeded by younger deposits, which, though of very different mineral cha-

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racters, unquestionably represent by position and fossils the Wenlock and Ludlow formations. I cannot more tersely and clearly express these relations than in the language which Professor Sedgwick himself applied to this region in 1845, *i. e.* seven years after the publication of the 'Silurian System*.' "Thus, the fossiliferous slates," he says, "present, first, *the Lower Silurian* rocks in a very degenerate form, and secondly, *the Upper Silurians* in a noble series†."

Nor can I convey a better idea of the succession of rocks in this district than by referring the reader to sections and descriptions by the same author published in 1846, to be studied in combination with his last memoirs of 1851-2. It is enough for me, on this occasion, to state, that these show a conformable succession of deposits from the crystalline, chiastolite schists, resting on a granitic nucleus or centre, up through Skiddaw slates, and a vast thickness of green slates and porphyry, to a thin band of limestone (Caradoc or Bala), and a considerable thickness of overlying flagstone, with Lower Silurian fossils, followed by what Professor Sedgwick has discovered to be the equivalent of the Caradoc sandstone—the 'Coniston Grits.' They are surmounted by a copious Upper Silurian series, in which the Wenlock and Ludlow formations are recognized by their position and fossils, though, as before said, their mineral aspect differs much from that of the original types.

This Upper Silurian series, forming the ridges on both sides of Windermere, and thence extending far to the south, consists in the lower masses of the Ireleth slates. These masses have a slaty cleavage oblique to the beds, are in parts calcareous, and have proved to be the equivalents of the Wenlock formation, more particularly resembling certain schists in Denbighshire which also assume a hard, arenaceous, slaty character. The overlying strata are sandy and pebbly. Then follow other coarse slates, grits, and flags, called by Mr. D. Sharpe 'Windermere rocks,' in which Lower Ludlow fossils occur, and a remarkable calcareous band, which is

* Though 1839 is on the title-page, the 'Silurian System' was brought out in 1838; its fossils and descriptions having really been made known to all practical British geologists between the years 1833 and 1836. The completion of the Map and Sections caused the delay in the final publication of the larger work.

† See Quart. Journ. Geol. Soc. Lond. vol. i. p. 443.

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seen at Underbarrow, Docker Park, &c. This band, it is worthy of note, is charged with starfishes similar to those which have been described as occurring in the Lower Ludlow rock of the Silurian region (p. 141). A very distinct representative of the Upper Ludlow succeeds, as proved both by position and fossils, but differing in being a siliceous flagstone, much harder than its equivalent in Siluria,—in short, akin to the strata of this age in parts of South Wales. The series terminates upwards in tilestones, which, on the banks of the Lune and near Kendal, are the exact counterparts of the uppermost zone in the Silurian region, and are charged with numerous fossils, some of the most striking of which are large crustaceans, Ceratiocaris, Eurypterus, &c. (see p. 155)*.

In this district, however, the ascending succession is interrupted, as Professor Sedgwick has shown†. Instead of the complete series of the Old Red Sandstone, which has been described in Shropshire and Herefordshire, and a conformable gradation and passage upwards into its overlying sandstones and marls, the Silurian rocks of all ages are at once unconformably overlapped by red masses, chiefly coarse conglomerates, which alone represent the great and complex group to be considered next in order.

Silurian Rocks of Scotland.—In the early days of Scottish geology, its illustrious founders, Hutton and Playfair, considered the schistose mountains in the south of Scotland to be void of all traces of life, until their able associate, Sir James Hall, detected a few fossil shells in a limestone at Wrae Hill, in Peebles-shire, which had been considered to be primary. The merit of transferring these strata from the primary to the transition class is also in great measure due to the late Professor Jameson; for though he valued lightly organic remains, as was then usual with the scholars of Werner, he gave a clear general view of the rocks.

* The reader who desires to study the data by which our present knowledge of the geology of the Lake district has been acquired, must read the various memoirs of Professor Sedgwick in the Proceedings of the Geological Society, vol. ii. p. 675, and the Quart. Journ. Geol. Soc. vol. i. p. 442, vol. ii. p. 106, vol. iii. p. 133, vol. iv. p. 216, vol. viii. pp. 35, 136; the Memoirs of Mr. D. Sharpe, Proc. Geol. Soc. vol. iv. pp. 23, 70; and those by Professor Phillips, Geol. Trans. 2nd ser. vol. iii. p. 1, and vol. iv. p. 95.

† Besides this general transgression and unconformity, it has been pointed out by Professor Sedgwick, that the 'Old Red' contains many fragments of the Silurian tilestones, which must have been solid before the conglomerate was formed.—Quart. Journ. Geol. Soc. vol. i. p. 449.

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It was not until some years after the publication of the 'Silurian System' that the researches of Professor Nicol first really indicated the relations of the Wrae fossils and the associated schistose masses to the known members of the series*; and, since then, other researches of that author, as well as of Moore, Sedgwick, Cunningham, Stevenson, Harkness, and myself, have brought the Scottish masses into a distinct comparison with their true types.

Silurian rocks, and particularly their lower members, are now known to occupy a very large region in the south of Scotland. Ranging on the whole from E.N.E. to W.S.W., they appear in considerable masses in Berwickshire and Roxburghshire, and thence spread out in still larger areas over the counties of Selkirk, Peebles, Dumfries, Kirkcudbright, Galloway, Wigton, and Ayr. In short, they constitute, on the whole, the undulating moory hills, which, from their prevalent wildness of aspect, have been called the South Highlands. Subjected, as they have been, to numerous eruptions of granite, syenite, porphyry, greenstone, and other igneous rocks, some of these ancient schists have long been known to geologists for the remarkable curvatures they exhibit in the sea-cliffs of Berwickshire. A drawing is annexed upon the following page, which represents such flexures and breaks, as seen in the cove, called Petticur Wick, near St. Abb's Head†.

As numerous similar contortions are visible also in the western prolongation of the same great series to the coast of Wigton and Ayr, we ought to be cautious in determining sections across the interior portions of a region, where the surface of the round and undulating hills is obscured by moss, heath, and bog, and where exposures of the bare rock are rarely to be met with.

Difficult, however, as it has been to fix upon the oldest portion of these inland masses of the Scottish greywacke, we have now

* For a complete historical sketch, see a notice by Mr. Hugh Miller (Witness newspaper, November 24th and 27th, 1852). A single fossil was found, but not described, by Laidlaw, the friend of Walter Scott; and orthoceratites were afterwards discovered by Mr. Charles Maclaren in the Pentland Hills, and noticed in his excellent work, 'The Geology of Fife and the Lothians,' 1839.

† The woodcut is taken from one of several rapid, clever sketches made in my note-book, in the autumn of 1833, by Sir Archibald Alison, the historian, from a boat, in which Sir John Hall of Dunglass and Professor Sedgwick were also my companions. Some of the lower buttresses are porphyries and other igneous rocks, which form the adjacent headland of St. Abb's. The convoluted masses form a portion of the Longmynd or basement rocks of the region.

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reached that starting-point. When traversing the tract between Dumfries and Moffat, in 1850, it occurred to me, that the dull

VIEW OF THE CLIFFS NEAR ST. ABB'S HEAD.
(From a sketch by Sir A. Alison, Bart.)

reddish or purple sandstone and schist to the north of the former town, which so resembled the bottom rocks of the Longmynd, Llanberis, and St. David's*, would prove to be of the same age, and therefore, the true South Scottish axis. For, this mass (similar to much of the hard rock of St. Abb's Head) evidently throws off anthracitic schists, with graptolites, both to the south and to the north. Professor Harkness established this order, after my visit, by detailed sections in that parallel, ranging by the Dyfe Water†. The same author has also communicated a memoir to the Geological Society, wherein he traces this axial line from the E.N.E in Roxburghshire to the W.S.W. across Dumfriesshire, where, covered for a space by the red sandstone (Permian) of Corncockle and Dumfries, it seems to trend to the granitic mountain called the Criffel, in Kirkcudbrightshire‡.

Professor Nicol, who led the way in opening out the proofs, both physical and fossiliferous, that the South Scottish Hills are really Silurian, has satisfied himself that this true axis of the oldest and hitherto unfos-

* Quart. Journ. Geol. Soc. vol. vii. p. 162.
† *Ibid.* vol. vii. p. 52, and vol. viii. p. 333.
‡ *Ibid.* vol. xii. p. 238.

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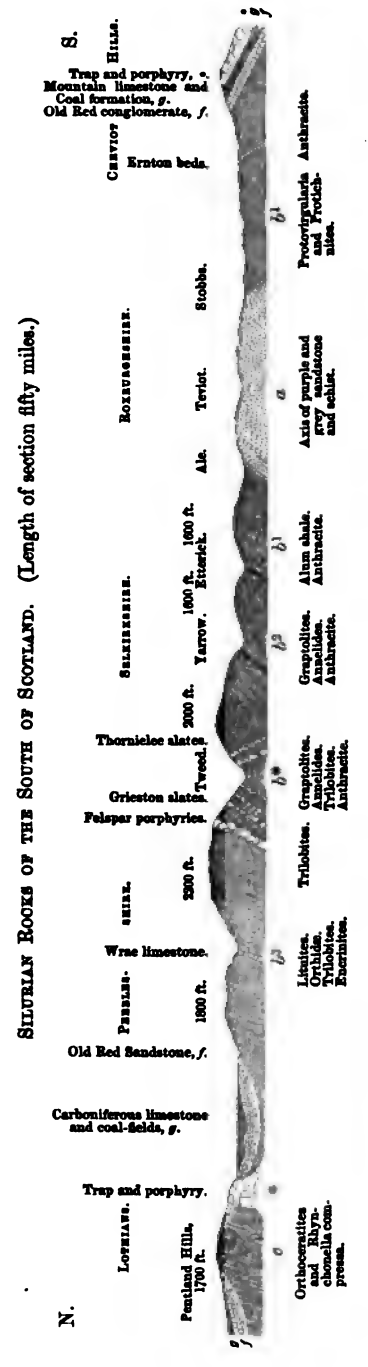

siliferous rock ranges by Teviotdale*. Proceeding from that centre, he has prepared the annexed general section, which (minor flexures being omitted) exhibits a short ascending section to the Cheviot Hills on the south, and a very long one to the Pentland Hills, near Edinburgh, on the north.

This traverse shows in the clearest manner an upward development from the lowest divisions of the series; so that after placing other transverse sections in parallel with it, whether along the east coast or from Dumfries and Moffat, we will then pass to the west coast, where we meet with higher and much more fossiliferous masses of the Silurian system.

Casting his eye over this diagram†, the reader will readily understand the comparison which is drawn between these Scottish strata and those of the typical region of Siluria and Wales, described in the second, third, and fourth chapters.

Beginning with the rocks which form the axis of Roxburghshire and Dumfriesshire, it is seen that they are of purplish or dull red colours, and that whether sandstones or alternating purple and grey schists, they are absolutely of the same composition as the bottom rocks of the Silurian region (Longmynd). Until very recently, no fossils had been found near this Scottish basement rock, but in 1854 Sir W. Jardine detected the Protovirgularia in purplish shale, which, in the parish of Applegarth, lies immediately

* Meeting of British Association, Belfast, 1852.

† Reduced from a large coloured section exhibited at the Belfast Meeting of the British Association for the Advancement of Science, 1852.

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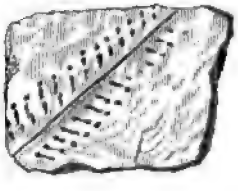
to the south of the axial line. At Binks in Roxburghshire, about three miles N.E. from Moss Paul Inn, and in the same range, Professor Harkness has observed physical evidences of deposits formed in very shallow water, in the ripple-marks, cracks of desiccation, and fine alternations of sand and mud. On one of the grey-coloured layers of the latter he detected in 1855 the track of a crustacean, a drawing of which is here given,

FOSSILS (23). TRACK OF A CRUSTACEAN.

Protichnites Scoticus, Salter, from Binks, Roxburghshire. Half natural size.



Impressions of the feet and sternal portion of the body.

as being the earliest sign of animal existence which we have obtained in Scotland. The creature which left these markings was probably a shrimp-like crustacean, as suggested by Professor Harkness, and analogous to the Hymenocaris (Salter) of the Lingula flags, of which a sketch is given (p. 45). The curious impressions above figured are not at all unlike those far larger prints which Prof. Owen has so well described, and which were found by Sir W. E. Logan in the Potsdam sandstone of Canada (Quart. Geol. Journ. vol. viii. p. 214). In this case, however, it would appear that a single pair of legs successively produced the imprints (not four or five or more, as in the Canadian tracks); and they are most likely to have been made by an animal swimming with difficulty in very shallow water, such as Prof. Harkness proves to have been the condition of the locality from physical evidence (Quart. Geol. Journ. vol. xii. p. 243). The reader will find in the fifteenth chapter, which treats of the Continental rocks of Silurian age, that the lowest fossiliferous rocks of the Thüringerwald contain the Protovirgularia associated with Nereites.

Although the axial dome, *a*, of purple rocks, for the most part arenaceous, throws off schists to the south as well as to the north, and that on both sides anthracite and traces of graptolites have been found in the beds marked b^1, the Silurian rocks are soon lost in the former direction under the red sandstone (Permian) north of the Solway Frith, or the Old Red and Carboniferous formations or porphyries of the Cheviot Hills. To the north of the axis of the Teviot, a long ascending section is presented to the observer, though it must be presumed that there are many flexures which are not marked in the diagram. In this direction, the schists and greywacke, b^1, which are in parts alum-slates (Etterick), may represent in time, as suggested by Professor Nicol, the schists of North Wales with Linguleæ, though as yet the Scotch strata have afforded no such fossils. These are surmounted by other schists,

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here and there containing thin laminæ of anthracite, b^3, which formerly gave rise to the notion of coal being subordinate to these rocks. It has been surmised that this anthracite resulted from the carbonization of sea-weeds, or possibly of graptolites and annelides; but the discovery by Nicol of some imperfect reed-like plants in the rock, with a minute vascular or tubular structure in the burnt residue of the anthracite, has led to the suggestion that some sort of grassy vegetation existed on the adjacent lands during this ancient period.

The anthracitic schists, b^3, contain a few phyllopod crustaceæ†, and many coiled annelides or sea-worms; they form the base of a vast thickness of graptolite schists, which, after a synclinal flexure in the Yarrow Hills, show another anticlinal in the valley of the Tweed, b^4. Whilst the Thornielee slates, with their graptolites and annelides (Nereites, Crossopodia), &c., are inclined southward, the Grieston slates, on the north bank of the anticlinal, plunge to the north, and then, for the first time in ascending order, we find trilobites in addition to the graptolites and annelides.

Associated with felspar porphyries (the whole representing the trappean and graptolitic group of North and South Wales) these rocks rise into mountains 2200 feet above the sea, and from them the sources of the Clyde, as well as of the Tweed, take their rise. Thence the northern dip being continued, the whole of the preceding masses are seen to be overlaid by the Wrae limestone of Peebles-shire, b^5, which, from its organic remains—trilobites and shells, has been paralleled with the Llandeilo limestone‡.

All the associated schists and other strata were, therefore, termed Silurian by Professor Nicol (1846); the more so as the fossiliferous limestone reposed on schists containing graptolites. In pursuing this traverse northwards, other overlying schists and slaty rocks are seen to overlie the Llandeilo? limestone of Wrae, though these are soon lost under and covered over by the Old Red Sandstone, f, and the Carboniferous formation of the Lothians, g. Beneath those deposits, f, g, we know not what flexures may occur in the subjacent or older rocks of the great intervening trough; but on reaching the Pentland Hills, hard schistose strata are again met with, nearly parallel to those we have left, and, like them, inclined to the N.N.W. at high angles. Under these circumstances only, it would be difficult to assign to the constituent strata

† Quart. Journ. Geol. Soc. vol. viii. p. 391. A larger species has since been found by Professor Harkness.

‡ Among the fossils of the Wrae limestone found by Professor Nicol are the Illænus Bowmanni, Salter; Harpes parvulus, M'Coy; Asaphus tyrannus, Sil. Syst.?; a species of Phacops; Cheirurus; Orthoceras arcuoliratum, Hall; Orthis calligramma, Dalman; O. biforata, Schlotheim; Strophomena (Leptæna) tenuistriata, Sil. Syst.; Salter, in Quart. Journ. Geol. Soc. Lond. vol. iv. p. 205, and Professor M'Coy in the 'Brit. Pal. Foss. Geol. Mus. Cambridge,' pp. 248, 374, &c.

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of the Pentland Hills any very definite place in the Silurian series. Penetrated as they are by igneous matter, and often in an altered condition, these strata, *c*, have, however, afforded some casts of orthoceratites, one of which, found by Mr. C. Maclaren, most resembles a Wenlock species. More recently, Mr. Geikie of the Geological Survey has detected the Rhynchonella compressa, also of Wenlock age. With these facts and the apparent order of superposition, we may infer, that the strata of the Pentland Hills are Upper Silurian, of age intermediate between the older rocks to the south and the uppermost Silurian of Lanarkshire, which will presently be spoken of.

A second traverse of the chain near the eastern coast, or towards the sea-board of the Lammermuir Hills, exposes the lower members of the series just described. There the Teviotdale anticlinal axis, *a*, is marked by the course of the Lower Tweed. The purple schist seen to the north of Berwick, the outlines of which have been sketched (p. 166), appears, therefore, to belong to the same bottom rocks of the series. Further northwards, higher beds, the equivalents of the Peebles-shire groups, occur, and in these, on the Dye near Byrecleugh, Mr. Stevenson of Dunse* has found a graptolite, an obscure coralline, and slates with annelide impressions. As these beds lie in the line of strike of the Grieston and Thornielee slates, they probably coincide with them in age. The predominating dip of the strata is to the north-west, showing a general ascending section, notwithstanding the numerous convolutions, which are beautifully seen on the coast, as already adverted to.

A third traverse of the South Scottish hills, made along the line of the Caledonian railroad†, exhibits the same general features, and many of the same details, as the preceding parallel sections. The Dumfries axis of the older and unfossiliferous greywacke, as before stated, throws off anthracitic and graptolitic schists to the south to Lockerby, and to Moffat to the north. The details of these must be sought for in the memoirs of Professor Harkness, who has shown to what a great extent some of the schists are charged with graptolites. Among them may be cited the wide-spread forms of the Llandeilo flags—Diplograpsus pristis, D. folium, D. teretiusculus, and Graptolites sagittarius—all found in the older rocks of Sweden; Graptolites lobiferus, a Bohemian fossil, with other species found in Lower Silurian strata elsewhere in the British Isles, or peculiar to these deposits. About twenty species have already been enumerated from this district alone‡. (See Foss. 11. p. 64.)

* See Proc. Geol. Soc. Lond. vol. iv. pp. 29 and 79; and Quart. Journ. Geol. Soc. Lond. vol. vi. p. 418. I long ago examined the purple greywacke or bottom rock, near Dunse, in company with Mr. William Stevenson.

† Prof. Nicol and myself examined this section together in 1850. See Quart. Journ. Geol. Soc. vol. vii. p. 137.

‡ See Harkness, Quart. Journ. Geol. Soc. vol. vii. p. 48; M'Coy, Paleozoic Fossils, Cambridge Museum.

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All these rocks, anthracitic and aluminiferous, which are charged with graptolites and annelides, dip northwards from Moffat to Abington, and thus pass under other masses visible in this direction. The latter, which occupy the tracts of the Lead Hills and other lofty summits, are metalliferous schists, in parts much altered, and penetrated by felspar porphyries with other igneous rocks. They were celebrated for yielding gold ore in the reigns of the Fourth and the Fifth James of Scotland. Associated with, or rather overlying them, is a rude breccia, partly calcareous, which may possibly represent the Wrae limestone of the diagram at p. 167. But, further northward, other and still thicker strata of Silurian age are visible, which are overlaid by the Old Red Sandstone and coal-fields of Lanarkshire. Though satisfactory in exhibiting a good ascending series from an unfossiliferous base of the sedimentary series, I consider this section less perfect in carrying out the order to beds on or above the horizon of the Llandeilo limestone, than that which is before figured (p. 167).

The fourth, or west coast traverse, from Luce Bay across Wigtonshire and part of Ayr, does not develope the order of the lowest masses, but adds much to our acquaintance with the more fossiliferous strata of the system, in exhibiting beds more copiously charged with fossils than any other Silurian rocks in Scotland*.

So contorted and fractured are the strata of the southern part of the series, that it is indeed no easy matter to place them in their exact relative places; even after much labour bestowed on the coast sections of his native county by my friend Mr. John Carrick Moore. The black glossy slates of Cairn Ryan, and certain red schists, might lead us, from analogy, and from their containing the same species of graptolites, to suppose that they represented the older portion of the previous sections which lie above the Longmynd or bottom rocks. On the other hand, they are associated with a coarse conglomerate, containing pebbles of granite and porphyry, with here and there blocks two feet in diameter; and this conglomerate so resembles a rock of the Ayrshire district about to be described, which clearly dips under certain fossiliferous schists (Kennedy's Pass), that the pebble-beds of Wigton and Ayr may be eventually placed on the same parallel. Along the coast, however, from Correrie Burn to the Stinchar River, they are separated by so much intrusive rock, that it becomes impossible, without long and continuous labour, accurately to coordinate the disrupted masses.

With the northern portion of this section I am best acquainted, and to it I now call attention. From the mouth of the Stinchar to Ken-

* Accompanied by Professor Nicol, I examined this tract in 1850. Our fossil collector was the late Alexander M'Callum, of Girvan, who searched every locality with great assiduity. See details in my Memoir on the Silurian rocks of the South of Scotland, Quart. Journ. Geol. Soc. vol. vii. p. 137.

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nedy's Pass, south of Girvan, the eruptions of porphyry, greenstone, and syenite are, indeed, on a grand scale (Knockdolian, Bennan Head, &c.). Owing to these great extrusions from beneath, the Silurian strata, accompanied by much serpentine and some metamorphosed schists, have there been thrown into at least three flexures in the distance of a few miles, on each of the axes of which, or on the Stinchar, Assell, and Girvan rivers, limestones of the Lower Silurian age are brought to the surface. These schists and limestones are overlaid in the contiguous troughs by other rocks, one portion of which, consisting of coarse conglomerates, and another of shelly sandstone, represent parts of the Caradoc or Bala rocks; whilst certain sandy and calcareous flagstones seem, by their fossils, to be equivalents of the Llandovery rocks and to indicate a passage into the lower member of the Upper Silurian.

Referring for details to the memoir above cited, I will here very briefly describe some of the salient features of these Ayrshire deposits. The limestones on the Stinchar and the Girvan rivers contain the following fossils:—Orthis calligramma, Dalm.; O. confinis, Salter; Leptæna sericea and L. quinquecostata; Cheirurus gelasinosus, Portl., with species of Illænus and Asaphus; Pleurorhynchus dipterus, Salt.; and corals of the genera Heliolites, Favosites, Omphyma, Strephodes, &c.

Most of the above species are Caradoc types; and with them is also found a species of the genus Maclurea* of Hall, which is peculiar to the Chazy limestone, one of the marked Lower Silurian deposits of North America.

These limestones, usually of dark grey colours, are associated with schists containing orthoceratites and graptolites, and then overlaid by fine, micaceous, dark grey shelly sandstones, and separated by thin courses of shale, in which many fossils occur, particularly in the Mulloch Hill, on the right bank, and in the Saugh Hill, on the left bank of the Girvan Water.

Among the fossils are,—Pentamerus oblongus; a variety of Atrypa hemisphærica, Sil. Syst.; Orthis reversa, Salt.; O. biforata, Schloth.; O. elegantula (canalis, Sil. Syst.); Rhynchonella angustifrons, M'Coy; Strophomena pecten, Dalm.; Bellerophon dilatatus, Sil. Syst.; Murchisonia cancellatula, M'Coy, a beautiful fossil; M. simplex, a Welsh species; Trochus Moorei, M'Coy; together with the well-known Silurian corals, Heliolites (Porites) interstinctus and H. tubulatus; Petraia subduplicata; Favosites alveolaris; Ptilodictya (Stictopora, Hall) acuta, Hall, or P. costellata.

Most of these species occur in the Llandovery rocks, and particularly the Pentamerus oblongus and Atrypa hemisphærica, which are the most abundant of the shells. There is also the Rhynchonella (or Hemithyris) angustifrons of M'Coy, a species before mentioned (p. 97) as occurring in the Lower Llandovery rocks of Wales. Again, among the trilobites, we have here the Lichas laxatus, common in the limestone at

* This species, which, though differing in some particulars, closely resembles the M. magna, Hall, has been so named by Professor M'Coy, who has described for Professor Sedgwick the fossils collected in this tract by Mr. John Ruthven.

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Bala in North Wales, and, in the very same matrix, the Calymene Blumenbachii. Now, although the last-mentioned crustacean has been found throughout nearly the whole system elsewhere, it is by far more common in the Upper than in the Lower Silurian. Besides, it is here associated with the Phacops Stokesi and Encrinurus punctatus, both of them fossils of the Llandovery rocks, and abundant in the Wenlock formation. So that in Scotland, as in England and Wales, and particularly as we ascend in the series, we meet with rocks in which the upper and lower types are mixed together.

It should be remarked, that in the sandstones of Saugh Hill, wherein the Atrypa hemisphærica abounds, we have, for the first time in the Scottish ascending series, Pentamerus oblongus*, Petraia elongata, and Tentaculites ornatus, which fossils, though occasionally found in lower strata, are peculiarly abundant in the upper portion of the Llandovery rocks of Siluria. The Mulloch Hill strata from their contents would rather appear to be referable to their lower division. In Scandinavia and North America, as in England, these fossils occupy an intermediate position between Lower and Upper Silurian.

Although the moory, mossy, and covered nature of the hilly grounds, intervening between the upcasts of the lower limestone and the shelly greywacke which they throw off, prevents the observer from making clear sections, I am now disposed to consider that Professor Nicol† was right in considering the black and greenish schists of Girvan as pertaining essentially to the Lower Silurian rocks, and as being inferior to the shelly Pentamerus sandstone of Saugh Hill. Professor Wyville Thomson has also arrived at the same conclusion. These schists contain a large orthoceratite, which Professor M'Coy has designated O. politum, associated with Lower Silurian graptolites. Here, also, we have the Orthoceras angulatum (virgatum), an Upper Silurian form. On the other hand, there is a large species, not to be distinguished from the O. vaginatum, Schloth., so common in the Lower Silurian of Scandinavia and Russia, and in addition O. bilineatum, a Lower Silurian fossil of America.

The genus Cyrtoceras is also found here; and with these cephalopods occurs a thin, finely striated Orbicula, the O. crassa, Hall, resembling

* Several of the species, particularly the Atrypa hemisphærica and Pentamerus oblongus, occur in the Clinton group which forms the base of the Upper Silurian of the United States. In Russia, the Pentamerus oblongus also occurs in limestone, or the lowest part of what is classed as Upper Silurian. The stratum in which this fossil there occurs, is, however, quite conformable to the beds beneath as well as to those above it. In addition to the Upper Silurian fossils mentioned in the text, Professor Wyville Thomson has recently informed me that he has detected, near Girvan, the Bumastus Barriensis of the Lower Wenlock in the same beds with the Calymene Blumenbachii.

† See Quart. Journ. Geol. Soc. vol. vii. p. 56.

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the O. striata of the Ludlow rocks. There are, moreover, both double and single graptolites,—both belonging to Lower Silurian species.

Whether, therefore, I judge from the clear proofs exhibited on the coast near Kennedy's Pass, where these fossiliferous schists repose upon a great mass of lower coarse conglomerate and sandstone, or from the specific character of many of their imbedded fossils, I now feel assured that the strata to the S. of Girvan are true Lower Silurian; whilst the Saugh Hill shelly sandstones are unquestionable equivalents of the Llandovery rocks. Certain rocks in the west of Ireland will presently be described which present just the same characters. On the whole there is no doubt, that the fossils of the highest member of the Girvan group indicate a passage into the Upper Silurian.

Although this is no place for lithological details, a few words must be said of a very striking conglomerate which lies low in the order of the strata. Among its rounded and waterworn pebbles, varying in size from musket-bullets to blocks of two and three feet in diameter, Professor Nicol and myself distinguished upwards of twenty varieties of rock. They consist of small specimens of earthy greywacke, and larger blocks of hard siliceous greywacke, Lydian stone, hornstone, felspar porphyries of various colours, greenstone, syenite, and granite.

Such conglomerates, which may be indicative of the powerful and long-continued action of waves on a coast, are, however, only to be viewed as local phenomena, and may therefore be looked for in various parts of this ancient series in Scotland; just as they have been shown to occur at various levels in the Silurian rocks of England and Wales. They occasionally appear, indeed, in the coarse grits of the Longmynd or bottom rocks; and coarse conglomerates occur in the same unfossiliferous subjacent greywacke or Cambrian of Carnarvonshire.

The shelly Silurians of Ayrshire being covered towards the north by the Old Red and Carboniferous deposits, there is no evidence in that tract of a younger order of things beyond what may be viewed as a transition from the Lower to the Upper Silurian.

On the opposite side of the South Scottish axis, however, the highly convoluted strata which form the southern headlands of Kirkcudbright Bay (Balmae Head and Little Ross), and the rocks on the east side of the Bay, are, judging from their fossil contents, of the age of the Wenlock shale. Hard and intractable as the Ireleth slates of Cumberland, which have been placed on the same parallel, and containing only very rarely nodules slightly calcareous, these argillaceous and siliceous schists have yielded a good many fossils. In them we find, it is true, the Lower Silurian forms, such as Orthoceras tenuicinctum (Chap. IX.) and the Leptæna sericea, Sil. Syst.; but from the same beds Mr. Salter has catalogued the following Upper Silurian types, viz. Phacops caudatus, Beyrichia tuberculata?, Orthoceras annulatum, Chonetes lata (Leptæna lata

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of the Sil. Syst.), Rhynchonella nucula, Pterinea lineatula, Grammysia (Orthonota) cingulata. With these are associated other fossils which pervade nearly the whole system, such as Atrypa reticularis, Halysites catenularius, Graptolites priodon, and Bellerophon trilobatus. The last fossil, which in England occurs in the uppermost Ludlow rocks, is associated, in Ireland, with lower types.

In this way we have no means of defining, with greater precision, the age of the fossil-bearing promontories of Kirkcudbright, than by saying that they overlie the great mass of the older Silurians, and contain a younger fauna. They appear, in short, to be more referable to the Wenlock than to the Ludlow formation. Through the discovery of the uppermost Silurian rocks in Lanarkshire (which are about to be mentioned), it might rationally be surmised, that the time was, when there existed a large and visible upward development of the youngest Silurian rocks also, on the southern side of the Dumfries axis, which ranged from the south of Scotland to meet the equivalents of the Wenlock and Ludlow rocks of the Cumbrian or Lake districts of England—all which deposits are now concealed beneath the sea.

But on the immediate shore of the Bay of Kirkcudbright, all such links have been omitted; for there the lower part of the Upper Silurians, as just described, is at once unconformably overlaid by strata of the Carboniferous era*.

Upper Silurian Rocks in Edinburghshire and Lanarkshire.—In the general section, p. 167, the overlying position of the schistose strata of the Pentland Hills has been indicated; and as the orthoceratites discovered in them most resemble those of the Wenlock formation, and as a Wenlock brachiopod, Rhynchonella compressa, has also been found in them, as before stated, by Mr. Geikie, there is little doubt that those schists are younger than any of the Girvan beds and are of Upper Silurian age. In the Pentland Hills, however, there is no further upward succession, and the beds in question, which are much penetrated by porphyry, are truncated and unconformably overlapped by Old Red Sandstone and Carboniferous rocks. The orthoceratite here figured, having been detected by my distinguished friend Mr. Charles Maclaren, has been

* The phenomenon of the unconformable superposition of the carboniferous strata (with mountain limestone fossils, &c.) to the Silurian rocks, along the coast of the parish of Kerrick, in Kirkcudbright, has been described in detail by Mr. Harkness, in a memoir read before the Geological Society, April 1853. This author explains by sections the extreme curvatures of all the rocks which he considers to be Upper Silurian, and parts of which he shows to have been shore deposits. He further indicates the dykes of porphyry which protrude, and has endeavoured to mark the line of separation between the Lower and Upper Silurian, which on the whole rise up to the N.N.W., their upper beds being conglomerates and coarse sandstones. Professor Nicol and myself examined Balmae Head in 1851. Mr. Stevenson described the nodular shale of Little Ross Head, Ed. N. Phil. Journ. vol. xxxv. The organic remains above alluded to were collected by the Earl of Selkirk and Mr. Fleming.

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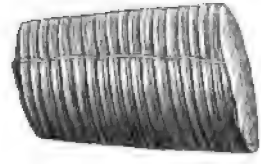
named O. Maclareni. It formed part of the collection of the deeply lamented, eminent geologist, Hugh Miller, who lent it to me for publication.

FOSSILS (24).

Orthoceras Maclareni, a new species.



Found in the Wenlock? strata of the Pentland Hills.

Unacquainted with any of the intermediate strata which may be found when these Upper Silurian rocks shall be traced from Edinburghshire on the E.N.E. to Lanarkshire on the W.S.W., I have satisfied myself that in the latter county, to the west of Lesmahago, there is an ascending passage upwards from clay-slates with calcareous nodules and a rare orthoceratite, into black schists with large crustaceans, which manifestly stand in the place of the uppermost course of the Ludlow rocks of Shropshire. This important fact was discovered by Mr. Robert Slimon of Lesmahago, who has thus opened out the newest page in the Silurian series of Scotland.

The relations of these dark grey schists to the inferior rocks as well as to the overlying Old Red Sandstone are seen on the banks of the Nethan River and other tributaries of the Clyde, particularly the Logan Water, on each of which the junction between the grey Silurian and the Old Red rocks is well exhibited. The Silurian beds rise up into several hills of considerable altitude, one of which, Nutberry, is 1715 feet above the sea.

The accompanying diagram will fully explain the relations of these Upper Silurian rocks to the overlying masses of old red sandstone and carboniferous rocks. It was in the beds, *a*, that Mr. Slimon of Lesmahago detected the remarkable crustaceans which I acquired from him, and which, being deposited in the Museum of Practical Geology, were first partially described by Mr. Huxley and Mr. Salter in the Journal of the Geological Society, as the sequel to the memoir wherein the geological relations of the tract were explained by myself*.

Rising out from beneath the lower Old Red, upon the Logan Water banks, these dark grey beds occupy precisely the same horizon as that uppermost zone of the Silurian rocks of Shropshire and Herefordshire which includes the bone-bed and the Downton Castle building-stone, and to which, where it graduates up into the Old Red, the name of

* Professor Ramsay and myself visited the localities near Lesmahago accompanied by Mr. Robert Slimon, and I afterwards prepared the accompanying section, and published it in a short memoir descriptive of the general relations of the deposits in this tract. Quart. Journ. Geol. Soc. vol. xii. p. 17.

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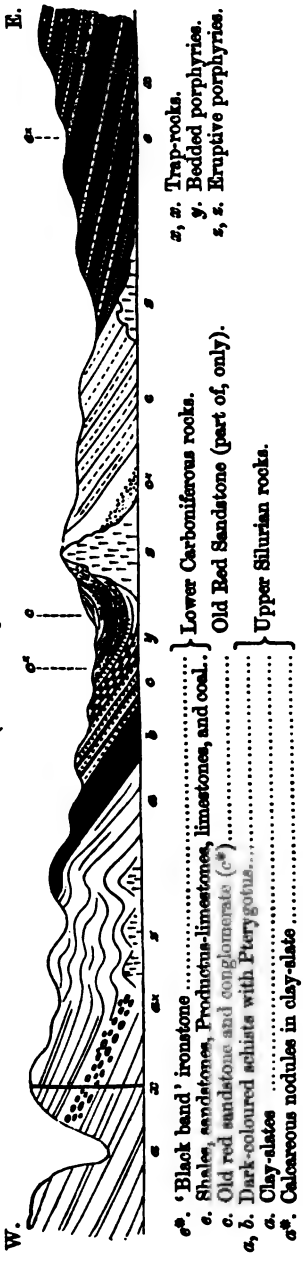

DIAGRAM EXHIBITING THE GENERAL RELATIONS OF THE UPPER SILURIAN ROCKS TO THE OVERLYING PALÆOZOIC STRATA IN THE PARISH OF LESMAHAGO. (From the Quart. Journ. Geol. Soc. vol. xii. p. 17.)

'tile-stones' has been given, as before explained. We have even the characteristic shells of the zone, the Trochus helicites and Lingula cornea.

The large crustaceans which chiefly characterize the dark clay-slate, *b*, were at first supposed to belong to a new genus of the family of Eurypteridæ, and were by Mr. Salter termed Himantopterus. By carefully collating, however, all their parts, he has satisfied himself that they belong to those Pterygoti which occur, as we have seen, at intervals throughout the Upper Silurian rocks, and are strikingly prevalent in their uppermost beds. In the annexed woodcut (p. 178) are represented the principal species discovered in Lanarkshire, and, with one doubtful exception (fig. 7), they are all distinct from any of the forms known on the same horizon in England.

The near alliance of these large crustacea with some of the minuter recent forms has been fully explained by Mr. Huxley in the memoir above quoted, and will be again touched upon in the chapter on Organic Remains. The number of species must have been very great; not less than nine or ten being known in Britain.

With them are associated, not only in Lanarkshire, but in Shropshire and Westmoreland, other very curious shrimp-like animals—possibly of the same group of Crustacea as the above mentioned. They have been called Ceratiocaris by Prof. M'Coy; and the fine specimens collected in the south of Scotland and other localities, have clearly shown that to this genus must also be referred those singular spine-like prongs which the same author described under the name of Leptocheles. A figure of the

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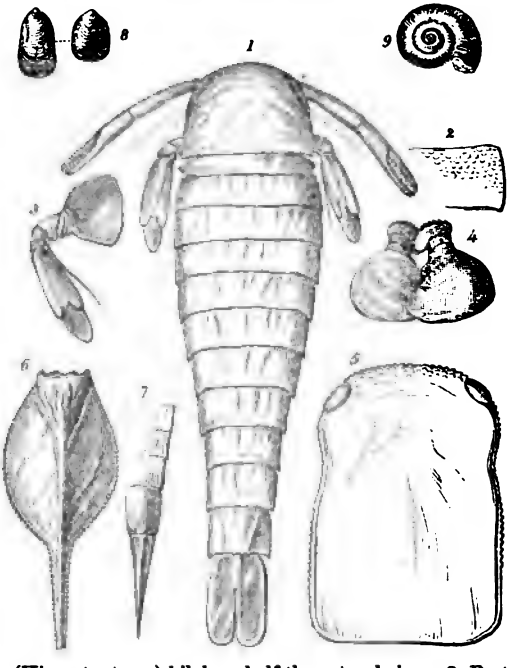
genus, as restored, was given in the Quart. Geol. Journ. for 1856, vol. xii. p. 33, and the fossil will be figured in Chap. X.*

The reader who refers back to the figure of Hymenocaris vermicauda of the Lingula flags, will see that animals of the same general form were in existence in the earliest time of the Silurian epoch.

FOSSILS (25). CRUSTACEA OF THE UPPERMOST LUDLOW ROCKS, LANARKSHIRE.



1. Pterygotus (Himantopterus) bilobus, half the natural size. 2. Portion of a body-joint, to show the peculiar sculpture. 3. Swimming-foot, natural size, but with the great basal joint incomplete. Fig. 4 shows a pair of these great foliaceous joints, with their inner serrate edges (the true mandibles are only indicated by their palpi in dotted lines, fig. 1).

5. Head (reduced to one-half) of the P. maximus, Salter. 6. Tail (reduced to one-fourth) of P. acuminatus, probably the same species as the last. 7. Tail and a few body-joints of P. lanceolatus. 8. Lingula cornea, Sil. Syst. 9. Trochus helicites, id.

Large crustaceans of the group of Eurypteridæ† (Burmeister), to which the Pterygotus belongs, have also been found in the tilestones of Westmoreland, and in these localities they are accompanied, as in Scotland, and at Ludlow, Kington, &c., by the small Lingula cornea.

In Southern Russia (Podolia) similar large crustaceans analogous to

* See Pal. Foss. Woodw. Mus. Pl. I E. fig. 7; Quart. Journ. Geol. Soc. vol. ix. p. 13; and 'Siluria,' p. 236, for a proof of Prof. M'Coy's acumen in distinguishing some of these crustaceans from the defences of fish.

† See Paleoz. Fossils, Woodwardian Museum, Fasc. 1.

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Pterygoti, were found in strata lying beneath rocks which are known to be of Devonian age, and to one of these Dr. Fischer gave the name of Eurypterus tetragonophthalmus. Recently M. Eichwald* has detected several species, one of which he figures as Eurypterus remipes, Dekay, in the Isle of Oesel in the Baltic,—*i. e.* in a limestone which my colleagues and myself referred to the highest Silurian stage, and which Professor Schmidt of Dörpat has shown by many of its fossils to be an exact equivalent of the Upper Ludlow rock†. In the North, therefore, as in the South of Russia, the zone under consideration, when clearly exposed, is everywhere characterized by large and peculiar crustacea, no one of which has ever been found in the Lower Silurian rocks.

In North America it has been long known, from the writings of Dekay and Harlan, that large Eurypteri occur in a so-called black greywacke slate at Westmoreland in Oneida County, New York, which will probably be found to be on the parallel of the Upper Ludlow rock. And even in Canada, as we learn from the collections of Sir W. E. Logan, species of Eurypterus or Pterygotus occur. The discovery of the large Eurypteridæ in the same geological zone in other distant regions is therefore peculiarly satisfactory.

Wherever these large crustaceans are found, and with them small Lingulæ and spiral shells, we may be sure that we are at or near the very summit of all rocks to which the term Silurian can be applied, and that the next overlying stratum belongs to the first *great* era of fishes, the Devonian or Old Red Sandstone; for the thin transition-band now under consideration still remains what I stated it to be twenty-one years ago, the lowest in which true vertebrated animals have been observed. As yet, not even a trace of such fishes has been detected in Scotland in the uppermost zone of the Silurian rocks.

Altered Scottish Silurians.—In the above brief sketch of the older strata of the south of Scotland, I have made few allusions to the igneous rocks which have been intruded among the Silurians. In numberless cases, whether around the granite of Criffel and Cairnsmuir, or the porphyry of Tongueland immediately to the north of Kirkcudbright, the schists which are in contact with such eruptive masses are so highly metamorphosed, that no one who looks at the effects can doubt as to their cause.

The view of much more extended metamorphism (due to a much grander cause) was indeed suggested by me in 1851‡. I then endeavoured to show, that certain bands of clay-slate, and of chloritic and micaceous schist forming the southern zone of the Highlands, with their interstratified limestones, were probably nothing more than metamorphosed

* Bull. Soc. Imp. Nat. Moscou, 1854, vol. xxvii. p. 100.
† Murchison in Quart. Journ. Geol. Soc. vol. xiii.
‡ See Quart. Journ. Geol. Soc. vol. vii. p. 168.

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Lower Silurian rocks, similar in age to the unaltered strata of the south of Scotland, and which, ranging parallel to them, come out to the surface again in broad undulations, associated with many granitic and other eruptive rocks, to the north of the great central Caledonian trough of Old Red Sandstone and the overlying coal-fields*.

One of these great undulations, which occur in the rugged mountains of the west called Argyll's Bowling-Green, exhibits an axis of mica-schist throwing off to the north and south great thicknesses of chloritic schist and altered sandstone with included and regularly stratified limestones; all trending from W.S.W. to E.N.E., parallel to the Silurian rocks of the south of Scotland.

In a subsequent memoir, Professor Nicol supported this idea, which he had long entertained, by striking facts and good reasoning. Describing the geological structure of Cantyre, and stating that the so-called mica-slate of that tract is only a partially altered micaceous sandstone, which seems almost to pass upwards into the Old Red Sandstone, he shows how all the other crystalline strata conform to and bend round the granitic nucleus of Goatfell in Arran. In confirmation of the probable identity of some of the crystalline strata of the north with the Silurian rocks of the south, he mentions the illustrative fact, that calcareous matter prevails most extensively towards the western extremity of both groups of rocks. In the South Scottish or Silurian strata no calcareous beds are known at their eastern termination; limestone only begins to appear in feeble courses in Peebles-shire, near the centre of the chain, and becomes very abundant (as above described) in Ayrshire. It is the same with the crystalline strata of the north. In the coast section from Stonehaven to Aberdeen, no calcareous bands occur; in Forfarshire and Perthshire several are known; they become still more abundant in the north of Argyleshire; and in Cantyre (as in Ayr) we have a great group of limestone rocks†.

The probability of the metamorphosis of the lower paleozoic deposits into those stratified crystalline rocks which occupy so large a portion of the Highlands of Scotland, has, since the publication of the first edition of this work, been reduced to a certainty as respects the north-western part of Sutherlandshire, by a discovery of Mr. C. Peach. That keen-eyed collector, though residing at Wick, had, in a rapid excursion to Durness, detected there certain fossil shells in the crystalline limestone, which in that region is subordinate to quartz rock. Now, according to Sedgwick, myself, and other geologists, including M'Culloch‡, these quartz rocks and lime-

* Quart. Journ. Geol. Soc. vol. vii. p. 160. † Ib. p. 23.
‡ See Sedgwick and Murchison, Trans. Geol. Soc. n. s. vol. iii. p. 125.

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stones, associated with and passing under micaceous and gneissose schists, and resting upon ancient gneiss, are overlaid on the east coast by the whole series of the Old Red Sandstone, which is made up of the materials of such pre-existing crystalline rocks: these will be treated of hereafter.

Judging then from their relative geological position, of which, after an interval of twenty-eight years, I reassured myself by a visit during the summer of 1855, I had little hesitation in suggesting that these rocks were of Lower Silurian age*. In them, my companion Professor Nicol and myself detected an orthoceratite, but too imperfect to be referred to any known species. The whorled shell first discovered by Mr. Peach, many polished sections of which were examined, threw indeed little light upon the subject; but specimens which the same zealous and unrivalled collector has subsequently detected in these rocks, and has sent to me whilst these pages are passing through the press, establish the correctness of my view.

"The fossils recently sent by Mr. C. Peach" (says Mr. Salter, to whom I referred them) "leave no doubt of the age of the beds in which they occur. The prevailing species must be particularly interesting to Canadian geologists, as it is a fossil which occurs in the 'Calciferous Sand-rock' of Beauharnais, and which, though undescribed, has received the MS. name of Ophileta compacta. The genus is doubtful, and may prove to be a subgenus only of the Raphistoma of Hall, consisting of species which have a wide umbilicus, bounded by a very prominent ridge, and straight-sided whorls.

"This species, as seen in Canada, grew full an inch and a half wide, and had as many as 6 or 7 whorls, flat above and with a sunken apex, and a very broad and wide umbilicus; so that the centre of the shell is much attenuated, and the inner whorls would easily break out, as in Mr. Hall's figure of O. levata, Pal. New York, vol. i. pl. 3. f. 4. The whorls of that species are much less carinate below, and the umbilicus is not nearly so wide as in the O. compacta. This last-mentioned shell will be fully figured and described in a Decade of Canadian fossils.

"It is curious that the Euomphalus? (Maclurea matutina) which accompanies the Beauharnais fossil in Canada, is found also in the Highland beds; and there is also another thick-whorled species.

"Again, a species of Pleurotomaria known in the Trenton limestone of America, the P. subconica, Hall, comes so very near to one of the

* See Report of British Association, 1855, Glasgow, Trans. of Sections, p. 85.

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Durness shells, that it may well be a variety only of that species. The Highland fossil has rather narrower whorls, and a somewhat broader band. There are species of Oncoceras also—a genus characteristic of the Trenton limestone."

As the age of these limestones and quartz rocks of the North Highlands, with their associated mica-schists, &c., has been a *quæstio vexata*—the lamented Hugh Miller having hypothetically suggested that they might be the representatives of the Old Red Sandstone and Caithness flags of the east coast, and Professor Nicol having recently considered them to be metamorphosed carboniferous rocks*,—it is satisfactory to me to find, that the old view of Professor Sedgwick and myself, with respect to their relative physical position, has been sustained by the independent evidence of fossils.

This discovery of N. American Lower Silurian fossils in the northern extremity of Scotland is also of deep importance in general geological reasoning; for it will be hereafter shown, that many of the same species of organic remains in rocks of this age extend throughout certain latitudes, over areas very remote from each other; or, in other words, that the Scandinavian, British, and N. American† Silurians have the same typical characters.

Silurian Rocks of Ireland.—Rocks which, from their included organic remains, must be classed as Silurian, occupy considerable portions of Ireland, whilst certain stratified crystalline masses of this kingdom are also probably (as in the Highlands of Scotland) of the same age.

In a retrospect of the progressive steps in the classification of Irish paleozoic rocks, allusion is first due to the veteran geologist Weaver‡. The earliest publication, however, in which any of the fossils of very ancient date were illustrated, was the valuable detailed Survey of parts of the north of Ireland by Colonel Portlock, who, from a small district of schistose greywacke, near Pomeroy

* Quart. Journ. Geol. Soc. xiii. p. 36.

† The great Maclurea of the Lower Silurian rocks of Ayrshire has been identified by Prof. M'Coy with the M. magna, Hall; and in Ireland, one of the Lower Silurian trilobites is an American species, the Isotelus gigas, Dekay.

Whilst these pages are printing off, Mr. Peach has undertaken, at my request, a fresh and more detailed examination of the W. of Sutherlandshire, and it is hoped that other discoveries may be announced in the Appendix.—July 26, 1857.—R. I. M.

‡ See Trans. Geol. Soc. Lond. vol. v. p. 117; 2nd ser. vol. v. p. 1 *et seq.*

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in Tyrone, described a multitude of interesting types, which enabled him distinctly to class these strata with the Lower Silurian group*.

When the first edition of Griffith's great Geological Map of Ireland appeared, the existence of rocks containing fossils of this age had been ascertained in a few localities only; the term Silurian being restricted by him to the precise spots from which those organic remains were obtained; and an important work on the 'Silurian Fossils of Ireland' was printed in 1846, under his auspices. But the progress of research, of late years, on the part of Mr. Griffith and his assistants, has much extended the areas in Ireland in which Silurian fossils occur, and has prodigiously increased the lists of organic remains.

The labours of the Government Surveyors, first under Professor Oldham, and now directed by Mr. Jukes, have since led to a still more methodical elucidation of these rocks. In this way, it has been ascertained that in the one term of greywacke, the following masses were grouped:—First, the Cambrian or dull red and purplish schist and grey quartzite, to the south of Dublin, the equivalent of the Longmynd, in which no other fossils, as before stated, have been found, except fucoids and two species of the small zoophyte Oldhamia (p. 28). Occupying the headlands of Bray, the mountains of the Sugarloaf, and the gorge of the Dargle, to the south side of Dublin Bay (and probably many other parts of the kingdom), these older or bottom rocks have recently been determined to be overlapped unconformably by all the overlying fossiliferous strata to which the term Silurian has been applied. With this physical severance, so completely in contrast to the order of succession in Shropshire and N. Wales (pp. 29, 30), there is, as might be expected, an absence in Ireland of the band of Lingula slates, which in other countries occupies the intermediate horizon.

The first recognizable strata which overlie the Oldhamia purple schists are dark-coloured slaty strata which at intervals are found to contain undoubted Lower Silurian remains. These fossiliferous schists occur in large but broken bands in the counties of Wicklow and Wexford, and reappear from beneath the Old Red Sandstone and carboniferous limestone in the cliffs of Waterford to the south of the bay of that name. Flanked, as these Lower Silurians are on their western side, by the dominant ridges of eruptive granite that form the Wicklow Mountains, they are there either in a crystalline or subcrystalline state, and thus exhibit a third condition of the greywacke of old authors, which, in the new maps of the Geological Surveyors, is distinguished by a darker tint.

* See Report on Londonderry and parts of Tyrone and Fermanagh. Dublin, 1843.

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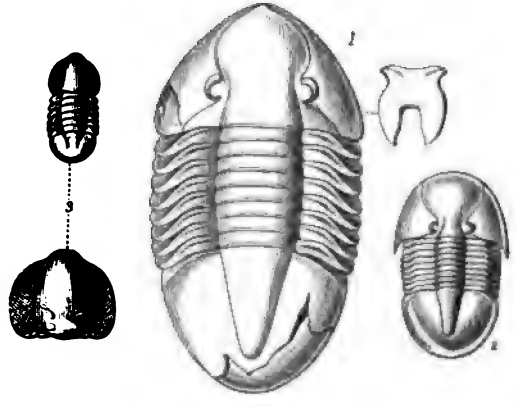
The silvery sheets of the well-known waterfall of Powerscourt are precipitated over highly inclined crystalline chloritic and micaceous schists of this class, which in Ireland are the equivalents of the crystalline rocks of Anglesea (see p. 54). In the central parts of the south of Ireland, or on the western side of the granite of the Wicklow Hills, the limestones and schists of the Chair of Kildare, which are replete with fossils, or the schists on the flanks of the Slieve Bloom Mountains, are classed as Lower Silurian*. So also are several masses of these rocks, at Portrane, to the north of Dublin, and especially near Pomeroy, in Tyrone, the richly fossiliferous locality just stated to be the first clear Silurian type described in Ireland. It is truly remarkable that so many of the characteristic Lower Silurian fossils should have been detected by Colonel Portlock in this small tract, and another of no larger dimensions in Fermanagh. Several of the Trinuclei and other trilobites, such as Phacops, Calymene, and Illænus, are identical in species with those of the Caradoc or Bala age from Shropshire and Wales; and so is it with the simple plaited Orthidæ, Leptænæ, and Strophomenæ, some spiral shells, and many orthoceratites (Plates 1–11). Commingled, however, with these are peculiar forms, first made known from this district, and which are very rare indeed in any other tract of the British Isles. Such, for example, among the trilobites are those figured in the tenth chapter,—the Remopleurides, Harpes, Amphion, and Bronteus. Such also are the smooth forms of Asaphus, called Isotelus by American

FOSSILS (26). LOWER SILURIAN TRILOBITES, IRELAND.



1. Asaphus (Isotelus) gigas, De Kay, and its labrum.

2. Stygina latifrons, Portl.

3. Æglina mirabilis, Forbes.

authors, which in Ireland, and on the other side of the Atlantic, are very abundant, whilst they are exceedingly rare in Wales or England, and are not known on the Continent.

* It is believed that the schists of Down may prove to be of the same age as the graptolite schists of the opposite Scotch counties of Wigton, Galloway, Ayr, &c.

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In Wexford, Waterford, and at the Chair of Kildare, the older strata have been so much disturbed and insulated, that it is difficult to detect anything like a sequence of order. Still the fossils, together with the physical characters of the rocks, clearly mark the Lower Silurian era. In the cliffs on the banks of the river Suir, below Waterford, and in the maritime headlands of Newtown near Tramore, and of Bon Mahon*, the schists, with feeble impure concretionary limestones, are underlaid by schists, which at Waterford are probably of Llandeilo age; the fossiliferous beds on the coast being rather referable to the Caradoc or Bala formation. These strata are charged with the simple plaited Orthidæ, trilobites of the genera Trinucleus, Ogygia, and Phacops, double graptolites (Diplograpsus), and corals, in as great abundance as in strata of the same age in Wales and Scandinavia.

In the western districts of Cork and Kerry, it has only recently been ascertained, that the masses of hard, purple and greenish grits and slaty rocks which rise into the loftiest mountains of Ireland around the Lakes of Killarney (Macgillicuddy's Reeks, Mangerton, &c.), and range to the Island of Valentia, are all of Devonian age. This is proved by the fact that in the promontory of the Dingle these rocks distinctly overlie strata charged with unquestionable Upper Silurian fossils. Many of these organic remains had indeed been long known, some of them having been figured and described by M'Coy from the collections of Mr. Griffith, with whom I first visited the district in 1842.

But the exact order of the rocks occupying the great mountainous mass of land lying between the Bays of Dingle and Tralee remained unravelled; so that in the first edition of this work an allusion could only be made to the hope then entertained, that the succession of the formations would soon be made known, and the relations of the fossiliferous rocks to the other deposits clearly indicated.

This end, which has proved no easy task, has at length been effected by the Irish Survey. The nomenclature which Mr. Griffith was formerly induced to adopt as respected these south-western tracts, and which is now changed, was very rational. Seeing there vast masses of chloritic and quartzose schists and other bands of very ancient-looking rocks that were unconformably surmounted by red conglomerates and sandstones, which latter he knew to be inferior to everything carboni-

* Most of the fossils described by Mr. Weaver in his memoir on the South of Ireland, Trans. Geol. Soc. Lond., 2nd ser., vol. v. p. 1 *et seq.*, are now known to pertain to the Carboniferous system; but certain localities which he notices, such as Smerwick Harbour or Ferriter's Cove, and Bon Mahon, near Waterford, which he termed transition, were long ago recognized by Mr. Griffith, and his assistant Mr. Kelly, to be Silurian: though with no precise reference to their age. In the public collection in Stephen's Green, Dublin, and in the rich cabinet of Mr. Griffith, the geologist will find an instructive assemblage of these Lower Silurian (Caradoc) fossils of Waterford.

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ferous, that vigilant and indefatigable observer naturally grouped the first-mentioned of these as Silurian, and so coloured his excellent Geological Map of Ireland.

Now, a chief portion of the rocks which Griffith termed Silurian were those mountain masses which are splendidly exhibited near Glengariff, and roll over in the lofty undulations around the Lake of Killarney before alluded to, reappearing in the promontory of the Dingle. Traversing these tracts from Bantry to Killarney in 1842, I even then came to the conclusion, that all these rocks must be equivalents of the Devonian system; for, together with certain red conglomerates and sandstones which overlap them, they are seen in several synclinal troughs to lie below the base of the Carboniferous system.

The difficulty, however, remained, of explaining the physical relations of these masses to the well-known fossiliferous Silurian deposits of Ferriter's Cove, Smerwick Harbour, and other places in the Dingle district. Were the Glengariff grits and Macgillicuddy's Reeks inferior or equivalent to such Silurian rocks of the Dingle, or superior to them?

In order to solve this question, Mr. Jukes specially employed the able field geologist, Mr. Du Noyer, in making a detailed survey, and in the end of August 1856, I revisited that ground, accompanied by Mr. Griffith, Mr. Jukes, and Mr. Salter, to endeavour to detect the real physical relations of the fossil-bearing Silurians of the Dingle promontory to the great schistose and quartzose masses now termed the 'Glengariff grits*.'

However difficult we found it to fix upon the precise spot where the oldest of the Silurian fossils could be detected†, it was quite manifest that in the westernmost headlands, Ferriter's Cove, Smerwick Harbour, Clogher and Doonquin Bays, there were unquestionable Wenlock remains in abundance, and that there the strata containing those fossils were overlaid by a clear and unequivocal representative of the Ludlow rocks, in which, though the strata are to a great extent lithologically different from those of the Silurian region, the same typical species of fossils occurred as in rocks of the same age in England and Wales.

Notwithstanding the obscuration of the interior country, these facts are plainly set forth in the coast cliffs between the Sibyl Head and Dunmore Head, which face the Atlantic and the Blaskett Islands. There, the Silurian strata occupying ledges on both sides of Ferriter's Cove,

* This term of 'Glengariff grits' was suggested by Mr. Jukes, and agreed to by Mr. Griffith.

† In one locality, however—the small cove called Coosathurig, under the Bull's Head promontory to the east of Dingle,—certain species were found, which Mr. Salter considers definitely to indicate a passage downwards from rocks with true Wenlock fossils into the Pentamerus or Llandovery rocks. At this spot a Pentamerus occurs, apparently identical with P. oblongus, Palæocyclus porpita, Favosites and Heliolites, and many large hollow-stemmed Encrinites, which are so characteristic of the Llandovery rocks. Further collections are much wanted from this wild spot.

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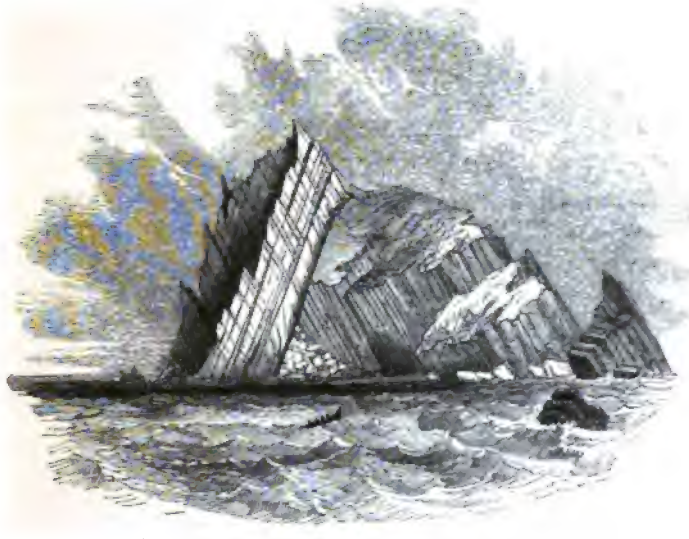
contain Wenlock fossils. To the north these are succeeded by pale purple unfossiliferous sandstones, including some lenticular beds of conglomerate, and these are overlapped unconformably by old red sandstone and conglomerate, the beds of which rise into the rugged Sibyl Head to the height of 670 feet above the sea.



THE SIBYL HEAD (SEEN FROM THE WESTERN OCEAN).

The strata rising up to the highest point, Sibyl Head, consist of old red sandstone and conglomerate. The lower ledges are Silurian (or Lower Devonian: see p. 189).

When, however, we follow the Silurian rocks to the south along the coast to Clogher Bay, and thence to Doonquin, we meet with a true ascending order, after a great fold in the beds at the Clogher Head. A flag-like series of green, grey, and purple schists and sandstones containing semi-calcareous and nodular bands, and associated with much interstratified volcanic ash and bosses of igneous rock, is there found to be charged with the following typical Wenlock fossils, viz. Euomphalus funatus and other species of that genus, Spirifer bijugosus, Rhynchonella nucula, Orthis elegantula, Atrypa reticularis, Proetus latifrons, with numerous corals, including the chain-coral,—and the trilobites Phacops caudatus and Encrinurus punctatus. In these strata we also find the Chonetes (Leptæna) lata in abundance, whilst in England it is the typical fossil of the Upper Ludlow rock.

The beds, which contain contemporaneous volcanic grit, and occasionally intrusive greenstones, are overlaid by strata which are best exposed inland, and in these (as between Doonquin and Croagh-marhin) there are many true Ludlow rock and Aymestry fossils; such as Penta-

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merus Knightii, Rhynchonella Wilsoni, R. navicula, Avicula reticulata, &c., together with Calymene and the small Lichas anglicus. In truth, however, the geologist would scarcely be able to draw those distinctions between the Wenlock and Ludlow rocks which are traceable in Siluria, but for the occurrence of a band of red slate and a thick development of fucoidal sandstones which here form the base of the Ludlow rocks. These fucoidal strata are well seen in Clogher Bay and Smerwick Harbour, their physical relations and organic characters having been traced out by Mr. Du Noyer and Mr. Salter. In the overlying beds with Pentamerus Knightii and the Cardiola interrupta, there are numerous species of corals, including a fine branched form of Heliolites, allied to the H. inordinata, Lonsdale, Sil. Syst. The curious annelide-tube, Trachyderma squamosa, Phill., is found also in these beds and in a vertical position; it is a Ludlow rock species.

The highest of the strata in which such fossils occur are purple-coloured and yellowish flag-like sandstones, and these are seen to pass gradually and conformably upwards into the greenish and purple slaty beds forming the base of the great series of Glengariff grits and schists which—not less than 7000 feet thick—occupy Mount Eagle and a long range of the Dingle coast. These beds are in their turn conformably surmounted by a thick suite of purple sandstones and conglomerates containing pebbles of Silurian limestone.

As then these last-mentioned rocks distinctly overlie all the strata with Upper Silurian fossils, there can be no hesitation in considering them to be the representatives of the slates and grits of Devonshire, or a chief portion of the Devonian system.

The annexed diagram, as prepared by Mr. Du Noyer, exhibits the general relations of the Silurian rocks of the Dingle promontory to the great superjacent masses of Devonian age, whether the Glengariff rocks (*e*), the red sandstones and conglomerates (*f*), or the overlying series (*z*). The last will be further commented upon in a subsequent chapter. In the mean time it is enough to point out, that the Upper Silurian and Ludlow rock fossils entirely terminate with the yellow and purplish sandstones (*d*), and these are surmounted by rocks in which no organic remains have yet been discovered.

In travelling along the west coast, or by the carboniferous rocks of Clare, to the county of Galway, the geologist again meets with tracts which are replete with Silurian fossils. Lying to the north of the picturesque mountains known as the Bins of Connemara, these fossil bands occupy the bold and precipitous sides of the deep bay of Killery, and range over a considerable space eastwards, by Leenane, Maam, and Oughterard, to the shores of Loughs Corrib and Mask.

Whilst on the eastern side of the island the eruption of the granite of the Wicklow Mountains has metamorphosed, as before said, the con-

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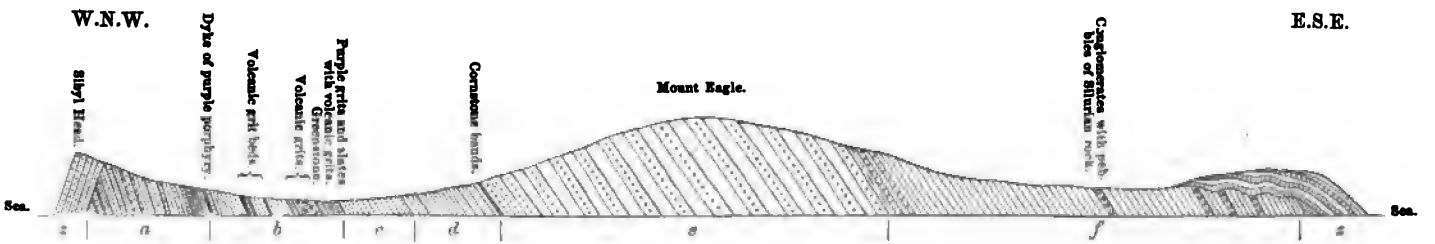
DIAGRAMMATIC SECTION SHOWING THE ORDER, THICKNESS, AND LITHOLOGICAL CHARACTER OF THE ROCKS OF THE DINGLE PROMONTORY.



a. Red and salmon-coloured sandstones and beds of conglomerate. No fossils. They appear to be the lowest beds, but are possibly the same as *d*, and brought in by a fault (see Appendix).

b. Alternations of pale green or grey and dull purple slates and purple-brown grits; succeeded by grey flags and slates with alternating beds of felspathic trap and ash; upper portion of group consisting of a thick deposit of volcanic grits (felspathic ashes), terminated by a bed of greenstone. Over all, a series of purple grits and slates with thin volcanic ash-beds. Wenlock fossils as in the text. Thickness 2500 feet, including 1000 feet purple beds and submarine volcanic ashes.

c. Green, brown, and grey flags and slates, containing Ludlow fossils as in the text; about 1000 feet.

d. Alternations of green and purple slates without fossils, terminating in beds of purple cornstone; 1500 feet.

e. 'Glengariff Grits.' Very thick-bedded massive grits and sandstones, with bands of green and purple slate; the grits obliquely laminated, often conglomeratic, and containing layers so highly calcareous as to form a kind of cornstone. No fossils known. Thickness about 8000 feet.

f. Purple grits, sandstones, and slates, containing in their upper portion bands of brightly coloured slates and flags, ripple-marked and sun-cracked, with conglomerate beds, some of the pebbles of which are rolled pieces of calcareous Silurian rock, containing Pentamerus oblongus, Encrinurus punctatus, and other Silurian fossils. No fossils except in these pebbles. Apparent thickness 4000 feet.

z, *z*. Overlying red and purple conglomerate and sandstone, which rest unconformably on all the inferior rocks, and pass conformably in the eastern part of the promontory into the base of the Carboniferous series.

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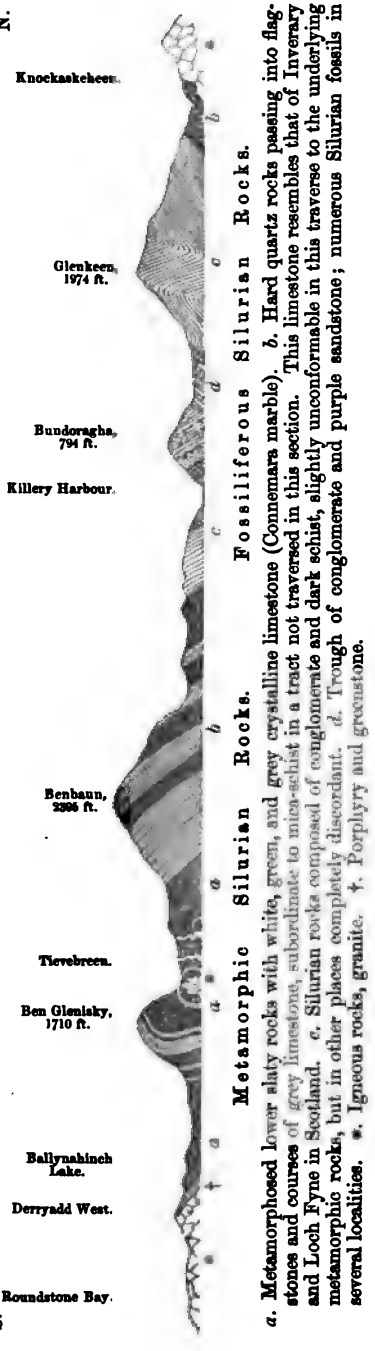

SECTION ACROSS THE BINS OF CONNEMARA, AND KILLERY HARBOUR. (From a coloured section by Mr. Griffith, prepared by Mr. Ryland Byron.)

a. Metamorphosed lower slaty rocks with white, green, and grey crystalline limestone (Connemara marble). *b*. Hard quartz rocks passing into flagstones and courses of grey limestone, subordinate to mica-schist in a tract not traversed in this section. This limestone resembles that of Inveraray and Loch Fyne in Scotland. *c*. Silurian rocks composed of conglomerate and dark schist, slightly unconformable in this traverse to the underlying metamorphic rocks, but in other places completely discordant. *d*. Trough of conglomerate and purple sandstone; numerous Silurian fossils in several localities. ***. Igneous rocks, granite. †. Porphyry and greenstone.

tiguous Lower Silurians; so in Connemara, on the west, we have a still more striking example of the metamorphism of a very large mass, which, in my opinion, must be also considered Lower Silurian. The annexed diagram is reduced from one of Mr. Griffith's transverse coloured sections across this remarkable district. After a personal survey of most of the Silurian tracts of Ireland, it has appeared to me best adapted to explain how certain crystalline rocks, which from their mineral aspect have hitherto been supposed to be of higher antiquity, are (like the Highland rocks before described) nothing more than the altered lower members of the sedimentary deposits under consideration.

In proceeding from Roundstone Bay on the south, low isles and headlands of granite, *, followed by syenitic and hornblendic rocks, †, throw off highly altered micaceous and quartzose schists, with courses of white and grey crystalline limestone, *a*, which, as you ascend the mountain of Ben Glenisky, one of the twelve Bins of Connemara, are seen to be followed by strong masses of granular, white quartz rock, *b* (manifestly an altered sandstone), which alternate with mica-slate.

Interlaced in the lower part of this series, and lying in depressions between Ben Glenisky and Ben Bawn (2300 feet above the sea), and thence

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ranging to the west, are certain crystalline limestones, one course of which is grey and white, and another is the beautiful green marble, or serpentine of Connemara. They are again overlaid by the granular quartz rocks and mica-slates, *b*, which, occupying the greater portion of these mountains, are in some places surmounted on their northern face (with a slight unconformity* only) by conglomerate, sandstone, and schists, *c*, containing fossils, at Lettershanbally, Blackwater Bridge, Leenane, Maam, and other places. Now, these remains, all unequivocally Silurian, belong by no means to the lowest members of the system. On the contrary, though some of them are found in the Lower Silurian strata, their prevalent species refer the beds rather to the Llandovery or intermediate rocks. In fact, the strata resemble, both zoologically and lithologically, some of the upper fossiliferous greywacke before described on the banks of the Girvan Water, in Ayrshire; many of the same species occurring in the two districts. Several of the Irish fossils are, indeed, more common in the Upper Silurian, both of England and Wales.

In the beds near Maam, Professor Nicol and myself collected remains, some of which would be considered Lower, and others Upper, Silurian; there being among the latter the Bellerophon trilobatus, first published from the tilestones, or summit of the Ludlow rocks. With the widely-spread fossils Strophomena depressa and Atrypa reticularis, which occur in nearly all the Silurian strata, we here met with Pentamerus oblongus, Orthis calligramma (virgata), O. reversa, Atrypa hemisphærica, &c., which elsewhere are known only in rocks of Llandovery age, associated with Rhynchonella Wilsoni and Retzia cuneata, Bellerophon trilobatus, and some lamellibranchiate shells, such as the Pterinea or Avicula retroflexa, and Cucullella antiqua, which were long ago described as true Upper Silurian fossils. Here, also, in the beds of junction with the mica-slates, are the chambered shells, Cyrtoceras approximatum, Orthoceras bullatum, O. ibex and O. angulatum,—species formerly supposed to mark the Upper Silurian only, but since also found in some of the lower strata. Among the trilobites we have even our persistent friend Calymene Blumenbachii, that ranges from Snowdon to Ludlow, and the Encrinurus (Amphion) punctatus, together with the genus Stygina, only yet known in Lower Silurian strata, and apparently the same species which is found

* In a traverse of this tract, which I made from Clifden to Killery Bay, in the company of Professor Nicol, the green marble seemed to me to be enclosed in mica-schist and quartz rocks. We also, however, met with a grey limestone, subordinate to the upper portion of the mica-schist, which, as in Argyleshire on both sides of Loch Fyne, exhibits many of the appearances of ordinary stratified limestone, in respect to bedding, joints, and way-boards; but we could detect no fossils in it. Though the above section exhibits the strata, *c*, containing Silurian fossils, reposing with a slight unconformity only on these micaceous rocks, there are many other such junctions (as around Maam) where the relations are quite discordant.

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in Tyrone, and Cyphaspis megalops, a Dudley fossil. Again, the corals from another locality (Kilbride) present us with such species as Favosites cristatus, F. Gothlandicus, F. multiporatus, &c., which are usually Upper Silurian types.

This statement is not made to weaken the value of the separation, on a general scale, of the Silurian system into two groups; but simply to show that there are tracts where the appropriation of certain strata absolutely to one or the other becomes impossible.

To sum up, then, we have seen in Dingle a copious and unmistakeable series of true Upper Silurian rocks and fossils. In Connemara and the adjacent tracts, and thence extending to Uggool in Mayo, the intermediate group of Llandovery rocks is strikingly apparent, though in fragments and patches only; whilst a multitude of organic remains, whether they be the well-defined forms described by Portlock from Tyrone, or those of the fossil-bearing schists of Kildare, Wexford, and Waterford, are unquestionably Lower Silurian, and for the most part of the Caradoc or Bala age. Where, then, is the lowest Silurian in Connemara and other tracts in which metamorphic rocks appear beneath the fossiliferous strata? My belief is, that the lower group is represented by the great underlying, crystalline masses of the Bins of Connemara, and that the limestones included in those mica-schists are nothing more than the Lower Silurians altered; some of them being of the age of Llandeilo, and others the equivalents of the Caradoc or Bala rocks of Wales.

In the Galway tract we cannot, indeed, pursue a clear ascending order, any more than in Scotland, though it is possible that a succession like that of the district of Dingle may be detected. As yet it has only been observed, that a coarse, chloritic, quartzose conglomerate overlies the fossiliferous beds in question;—a conglomerate which, according to Mr. Griffith, rises into mountainous masses on the north side of the Killery Bay. Alternating with green and purple slate and interstratified felspar porphyries, †, these upper rocks, after an undulation, repose upon a vast mass of greenish, grey, and reddish slate, *c*. The base of the fossiliferous series to the north of the Killery Harbour is composed of a dark and reddish-brown sandstone, under which is a conglomerate of mica-schist and other rocks; the whole resting, as on the other side of the trough, on mica-schist, *b*. (See section, p. 190.) Then follows a boss of granite, * (Knockaskeheen), which throws off crystalline schists on both flanks,—the masses in the north being bounded by the unconformable and horizontal carboniferous limestone of Clew Bay in Mayo.

Altered Irish Silurians.—Seeing that we cannot trace downwards fossils of higher antiquity than the middle portion of the Silurian series, it seems fair to infer, that the subjacent quartz rock, mica-

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schist, and stratified limestone of Connemara are really the representatives of the Lower Silurian rocks.

The progress of research will also, I trust, bring out other evidences to support the views respecting metamorphism derived from a survey of the Connemara tract, and which, after the proofs of an Upper Silurian series obtained in the Dingle district*, seems to be rendered still more probable. May not, indeed, this view of the metamorphism of Lower Silurian rocks be applied to some of the crystalline rocks of Donegal; and may they not eventually be brought into connexion with the true Lower Silurian oases of Fermanagh and Tyrone? This is a task worthy of the Irish Government Surveyors, and which, I have no doubt, they will ably accomplish. No one who has examined the small patch near Pomeroy could imagine, from the aspect of the schists, that it would have proved as highly fossiliferous as it did under the scrutiny of Portlock. Hence we need not despair of finding the occupants of other former burying-places in various parts of the large area of Ireland, over which Silurian rocks are believed to extend; though these deposits, being to so great an extent metamorphosed, are necessarily sterile in organic remains.

Some of the most characteristic of the Irish Silurian fossils will be noticed in the two ensuing chapters; but a full acquaintance with them must be sought for in the works of Portlock and M'Coy, and in the tables of Griffith. They will also, I trust, hereafter be illustrated in the publications of the Irish Survey.

* In a preceding page (187), an omission has accidentally occurred in not stating that the sketch of the Sibyl Head, showing the red conglomerate resting upon the edges of older rocks, is from the pencil of Mr. Du Noyer. That able observer, to whom I am also indebted for the general diagram, p. 189, has, in conjunction with Mr. Jukes, arrived at the conclusion, after reiterated surveys of the whole promontory of the Dingle, that the beds immediately underlying the conglomerate of the Sibyl Head are not, as at first represented in the general diagram, the lower part of the ascending series, *a*, but are, on the contrary, a member of the upper portion of the Glengariff grits, *f*, termed the Dingle beds. It is now believed, that a great fault traverses that part of the headland near the spot where a dyke of porphyry is noted, by which the Dingle beds, *f*, are thrown into this anomalous position. Though important in clearly defining the physical features in a district, wherein the strata are so much disturbed, this view does not in any way invalidate what has been stated respecting the clear ascending order from true Upper Silurian rocks charged with Wenlock and Ludlow fossils, *b*, *c*, of the same diagram (p. 189), into the overlying masses of slaty schists and hard grits, *d*, *e*, *f*, which are, in my opinion, the unquestionable representatives of the greater portion of the Devonian or Old Red series.

It must also be understood, that in the general diagram, p. 189, all the folds, contortions, and minor breaks of the strata, as well as the intruded rocks, have been omitted. These are faithfully delineated in the sections prepared by the Surveyors, under the skilful direction of Mr. J. Beete Jukes.—*September* 28, 1857.

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Note.—Mr. Jukes has forwarded to me a description of a band of anthracitic coal, which occurs in ancient clay-slate and hard grits at Kilnaleck in the county of Cavan, and to which my attention was formerly directed by Mr. Kelly (see Appendix to first edition, p. 493). The strata in which this anthracite lies extend from Cavan through the counties of Louth, Monaghan, Armagh, and Down, and from their composition as well as from their strike to the N.E., they are supposed to be of the same age as the anthracitic Lower Silurian schists of Dumfriesshire in Scotland already described (p. 169). As this course of Irish anthracite, which varies in thickness from 1 to 12 feet (ranging in a nearly vertical position with its associated beds from S.W. to N.E.), is a fuel of better quality (in short, a real coal) as well as of larger dimensions than any similar substance hitherto noticed in the Silurian rocks, the phenomenon will be described in the Appendix.

Vertical Dimensions of the Silurian Rocks of the British Isles.—We have as yet no means of calculating, even approximately, the thickness of the older deposits of Scotland and Ireland which have been treated of in this chapter. In both regions large spaces occur throughout which the framework of the subsoil is so obscured and hidden, that it has not yet been ascertained whether there is a continuous ascending order, or if the same strata be repeated by flexures, the upper portions of which have been cut off.

In the typical region of Shropshire and the adjacent Welsh counties, as described in the preceding chapters, we can, however, appeal to the estimates of the Government Surveyors. In Shropshire, the Longmynd rocks (the Cambrian of the Survey) are supposed to have the vast thickness of 26,000 feet, or about three times that of the same strata in North Wales; but even admitting that these rocks are to some extent repetitions (of which, however, I see no evidence), their dimensions, according to any estimate, must still be enormous.

My originally described Lower Silurian strata of Shropshire to the west of the Longmynd, from the Stiper Stones upwards, including the Llandeilo formation, exhibit a thickness of 14,000 feet; and if we add to this mass the thickness of the Caradoc sandstones, limestones, and shales lying on the eastern slopes of Caer Caradoc, which have been described at p. 70, and amount to about 4000 feet, we ascertain that in the typical tract of Shropshire alone the Lower Silurian rocks attain the dimensions of 18,000 feet. These dimensions are, indeed, nearly equal to those which have been estimated for their equivalents in the lofty, slaty, and rugged region between the Menai Straits and the Berwyn Mountains,

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where the Surveyors have estimated the total thickness of all the strata of like age at 19,000 feet.

In the lowest part of these enormous accumulations of sedimentary strata, the rarest trace only of fossils has been found; and in the Lingula flags, the lowest of the Silurian zones, organic remains increase so slightly, that comparatively few forms have yet been detected in them. In the great Llandeilo and Caradoc formations, however, the trilobites, mollusks, and corals augment enormously and amount to many hundred species.

The Llandovery rocks, intermediate between the lower and upper divisions, swell out in some parts of Wales to a thickness of 2000 or 3000 feet; and, though in many tracts this zone is of small dimensions, it is not poor in the variety of fossil species.

The Upper Silurians, consisting of Wenlock and Ludlow rocks, attain nowhere a greater thickness than 5000 or 6000 feet; and yet this younger group is as replete with fossils as the Lower Silurian strata, the dimensions of which are so much larger.

In conclusion, it is, indeed, well to reflect upon the fact, that notwithstanding their enormous physical development of not less than 26,000 or 27,000 feet, the British Silurian rocks are not more copiously charged with organic remains than the strata of the same age in Scandinavia, where the total thickness of the Lower and Upper Silurian, welded together in one physical mass, does not exceed 2000 feet, as will be shown in a subsequent chapter.

Postscript.—*Lower Silurian Rocks in the Northern Highlands of Scotland.*—When the first edition of this work was published, I entertained the belief, in common with my early associate Sedgwick, and our precursor M'Culloch, that the striking mountain masses of red conglomerate and hard grit on the N.W. coast of the Highlands*, which rest in layers more or less horizontal on low and gnarled bosses of very highly inclined and ancient granitoid gneiss, as represented in the

* My first visit to the west coast of the Highlands was made in 1826, accompanied by Lady Murchison, during which my attention was almost exclusively devoted to descriptions of the Oolitic and Liassic strata of the E. and W. of the Highlands (see Trans. Geol. Soc., 2nd ser., vol. ii. p. 293, &c.). In the following year Professor Sedgwick and myself made that survey which enabled us to write the memoir upon the Old Red Sandstone of Scotland, which is printed in the Geological Transactions (n. s., vol. iii. p. 153). Although we encountered bad weather in Assynt, which prevented us from making accu-

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vignette which is given at p. 198, were really a part of the Old Red Sandstone of Scotland*. A re-examination, however, of those tracts in 1855† compelled me to abandon that view. I then saw, that portions at least of these conglomerates, often in a semi-crystalline state, and resting on the oldest or granitoid gneiss of the Highlands, as around Loch Assynt, were really inferior to those quartz rocks and limestones in the prolongation of which to the north coast of Sutherland Mr. C. Peach had detected fossils which enabled me to suggest, that they belonged to the older Silurian rocks (p. 181)‡.

Since the preceding sheet was printed, and during my absence on a geological tour abroad, additional researches undertaken, at my request, by Mr. C. Peach (see Note, p. 182), have elicited much more numerous and more perfect fossils than were previously known; and these enable me to re-affirm unhesitatingly, that the quartz rocks and limestones of the N.W. Highlands are truly of Lower Silurian age.

The most striking of these fossils is the Maclurea, a genus which, as yet, has alone been found in deposits of that age. One species was, indeed, figured in the first edition of this work, and has already been alluded to (p. 172), as occurring in the South of Scotland; but the Sutherland form, being undescribed, will justly receive the name of M. Peachii.

The other organic remains belong to the genera Ophileta, Oncoceras, and Orthoceras, with small gasteropods, annelides, &c. These shells are all closely allied to (one of them identical with) N. American species, so well described by Mr. James Hall. In short, they represent the fauna of the Lower Silurian rocks of Canada and the United States, from above the Potsdam sandstone to the Trenton (Llandeilo) limestone, inclusive§. Let us also observe, that the Scottish and American

rate distinctions among the rocks of that tract, we even then noted a conglomerate and grit as underlying to some extent the quartz rocks and limestones of Sutherland. At that time no one had begun to classify any fossiliferous strata below the Old Red Sandstone, and all the old Scottish conglomerates, which are now being referred to Cambrian, Silurian, or Devonian ages respectively, were then grouped with the Old Red Sandstone. Having been prevented from detecting the unconformity on the west coast which has since been noticed, we naturally concluded, with M'Culloch and others, that the conglomerate of the west coast was of the same age as that on the east; an erratum which will be specially dwelt upon in the 11th chapter, when treating of the Old Red Sandstone.

* See M'Culloch's Western Islands of Scotland; Conyngham's Mem. Highland Society, vol. xiii. p. 73; Nicol, Journ. Geol. Soc. vol. xiii. p. 17.

† Accompanied by Prof. J. Nicol.

‡ In reference to the theory broached by Hugh Miller, that these quartz rocks and limestones might be the equivalents of the Old Red Sandstone series of the east coast (see p. 182), let me say, that if my eminent and lamented friend had lived to see the fossil evidences which prove them to be of Lower Silurian age, he would, I doubt not, with his accustomed candour, have been the foremost to adopt the improved classification.

§ See the observations of Logan and Salter, which show that the characteristic fossils of each of these limestone-bands may be found associated in the limestone of the Ottawa River; Report of the British Association for the Advancement of Science, 1851, Sect. p. 63.

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groups resemble each other, to a great extent, in mineral composition, as well as in their fossil contents. All these remains will be noticed in the ensuing chapter, with woodcuts representing the principal forms.

The age of the fossiliferous rocks being thus definitively settled, it follows, that the subjacent red sandstone, grit, and conglomerate must form either the natural base of such Lower Silurian, or belong to the remoter Cambrian era. Now, from observations which were made last year, combined with the discoveries of Mr. Peach, it is certain that the first of these views cannot be entertained; for it has been clearly demonstrated that the lowest beds of the quartz-rock series overlap transgressively or unconformably the edges of the subjacent red sandstone and conglomerate*. By this phenomenon we are taught, that an interval elapsed between the completion of the pebbly and gritty beds that constitute the upper masses of the mountains represented in the following vignette, and the commencement of the deposit of those sandy and calcareous beds, since converted into quartz and marble layers, in which the Lower Silurian fossils were entombed (c^1 & c^2 of the section at p. 199).

It follows, therefore, that the subjacent red sandstone and conglomerate, *b*, reposing upon the most ancient gneiss known in Scotland, are to be considered of the same date as the similarly constituted purplish-red and pebbly sandstones of the Longmynd; which, in the typical region of Shropshire, underlie all the Silurian strata (p. 23). There, however, as well as around Harlech in N. Wales, these Cambrian rocks graduate upwards into the superjacent Silurian rocks, and the period occupied in the development of the formation of Lingula flags fills up the interval which is marked by the break in the N.W. of Scotland. The Durness

* Although Prof. Nicol and myself saw clearly, in the summer of 1855, the *infraposition* of a red conglomerate and sandstone to the quartz rocks and limestones of Assynt (as observed also by Hugh Miller), we were prevented by storms from sufficiently extending our observations to ascertain if there was any break between these two deposits. Being aware that my friend Colonel James, R.E., the Superintendent of the Ordnance Survey, was about to explore these tracts on a tour of duty in the following summer, and knowing his talent as a field geologist, I requested him to look to the relations of the beds; and I have much pleasure in stating, that I was first made acquainted by him with the fact of the unconformability of the older to the younger formation along the flank of Suilvein (July 1856). Later in that summer, Prof. Nicol observed the same phenomenon on a larger scale, and skilfully ascertained that it extended over a larger area of the western shores of the Highlands. See his memoir 'On the Red Sandstone and Conglomerate and the superposed Quartz-rock Limestone and Gneiss of the N.W. coast of Scotland,' Quart. Journ. Geol. Soc. Lond. vol. xiii. p. 17, &c. with clear and accurate sections. It is right to remark, that part of the overlying group here spoken of as gneiss is merely one of the Lower Silurian rocks rather more altered than the other strata of quartz, marble, &c., and is of a very different character from the immeasurably older granitoid gneiss, which is represented in the following sketch and section, as forming the buttresses on which the red sandstones and conglomerates of Cambrian age are seen to repose.

The younger gneiss, extending in undulations to the E. of Loch Eribol, was, indeed, long ago described by Prof. Sedgwick and myself as overlying those limestones and quartzites which have now been ascertained to be of Lower Silurian age (see Trans. Geol. Soc. Lond., n. s., vol. iii. p. 125, &c.).

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fossils are of the Lower Llandeilo age, and indicate a zone but little younger than the Potsdam sandstone of N. America, which I regard as equivalent to the Lingula flags of England, the alum slates of Scandinavia, and the 'Zone primordiale' of Bohemia. It is, therefore, a fair inference, that in the north of Scotland the base of the Silurian system is represented by the lowest quartz rock (c^1 of the opposite section), which is seen to repose transgressively on the Cambrian rocks.

MOUNTAINS OF THE WEST COAST OF SUTHERLAND AND ROSS.

The above pictorial view, from a sketch in my possession taken by that accomplished Highland chieftainess the late Duchess Countess of Sutherland, represents the three isolated mountains of Coul-beg, Suil-vein, and Coul-more. The strata of red sandstone and conglomerate (now known to be Cambrian; b of the opposite section) may be distinguished by the horizontal lines marking the stratification. The lower buttresses of the mountains are composed of the ancient gneiss with granite veins (a of the section).

Hugh Miller's description of these great masses of red and chocolate-coloured conglomerate and hard sandstone, which are seen reposing upon the oldest gneiss of Scotland, and which, as above explained, are overlaid in their range to the north by the Lower Silurian quartz rocks and limestones of Assynt and Durness, is so eloquent and so true, that I gladly cite a portion of it. "Rising over a basement of rugged gneiss hills, that present the appearance of a dark tumbling sea, we descry a line of stupendous pyramids from 2000 to 3000 feet in height, which, though several miles distant in the background, dwarf, by their great size, the nearer eminences into the mere protuberances of an uneven plain. Their mural character has the effect of adding to their apparent magnitude. Almost devoid of vegetation, we see them barred by the lines of the nearly horizontal strata, as edifices of man's erection are barred by their courses of dressed stone; and while some of their number, such as the peaked hill of Suil-vein, rise at an angle at least as steep and nearly as regular as that of an Egyptian pyramid, in height and bulk they surpass the highest Egyptian pyramid many times. Their colour, too, lends to the illusion. Of a deep red hue, which, in the light of the setting sun, brightens into a glowing purple, they contrast as strongly with the cold grey tone of the gneiss tract beneath, as a warm-coloured building contrasts with the earth-tinted street or roadway over which it rises."

In following these metamorphic strata from Sutherland along the west coast of Ross-shire, I entertained no doubt that the crystalline lime-

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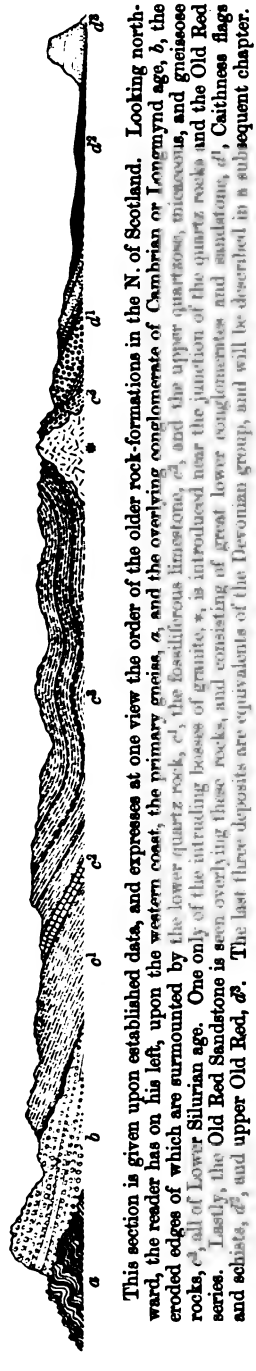
GENERALIZED SECTION ACROSS THE NORTH OF SCOTLAND.



This section is given upon established data, and expresses at one view the order of the older rock-formations in the N. of Scotland. Looking northward, the reader has on his left, upon the western coast, the primary gneiss, *a*, and the overlying conglomerate of Cambrian or Longmynd age, *b*, the eroded edges of which are surmounted by the lower quartz rock, c^1, the fossiliferous limestone, c^2, and the upper quartzose, micaceous, and gneissose rocks, c^3, all of Lower Silurian age. One only of the intruding bosses of granite, *x*, is introduced near the junction of the quartz rocks and the Old Red series. Lastly, the Old Red Sandstone is seen overlying these rocks, and consisting of great lower conglomerates and sandstone, d^1, Caithness flags and schists, d^2, and upper Old Red, d^3. The last three deposits are equivalents of the Devonian group, and will be described in a subsequent chapter.

stones on the shores of Loch Keeshorn, Loch Carron, Loch Alsh, and Loch Duich, with the associated chlorite-schist, mica-schist, and quartz-rock, are of the same age as the lower quartz and limestone of Sutherland, like which they are also overlaid by the rock mapped by M'Culloch as gneiss (c^3 of section). To satisfy myself on this point, I traversed the lofty watershed which separates Kintail from Strath Glass, ascending from Inverinat through the striking pass, the Bealloch of Kintail, to Loch Affric, and there found a vast thickness of regularly bedded gneissose, micaceous, and quartzose rocks, all of which have the same strike as the fossiliferous rocks of Sutherlandshire; and which, despite of undulations, have also a prevalent dip to the E.S.E.

The accompanying long section shows the general relations of all these North Scottish rocks from the most ancient gneiss through the Cambrian and Lower Silurian to the summit of the Old Red Sandstone on the eastern coast.

In concluding these observations on the Silurian rocks of Britain, let me specially call the attention of the reader to the direct bearing which the discovery of the above-mentioned fossils in Sutherland must have in determining the true geological age of a very large portion of the stratified crystalline rocks of the western and central Highlands.

It is, indeed, gratifying to me to find, that the theoretical view I published some years ago, and have repeated in this work (see p. 179), seems now to be fully sustained—viz. that

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the great mountainous expanses of argillaceous, chloritic, and micaceous schists with intercalated quartz rocks, marble, and limestones, which constitute the chief portion of the so-called primary rocks of the west of Scotland, and extend from Dumbartonshire, through Argyllshire and Inverness-shire, into Ross-shire and Sutherland, are on the whole the metamorphosed prolongations of the Lower Silurian rocks of the South of Scotland.

We now further know, that these crystalline masses of Lower Silurian age overlap those red sandstones and conglomerates which, much older than the Silurian red conglomerate of Ayrshire (p. 171), are doubtless the equivalents of the Longmynd or Cambrian rocks; whilst the latter repose upon ancient gneiss rocks, which are nowhere exhibited in England and Wales.

The natural sections of the British Isles enable me, therefore, to sustain the view put forth in the earlier pages of this volume, which presented to the reader the general order of the primeval rocks*.

* See the generalized diagram at p. 21, in which gneiss is represented as the fundamental rock, though not seen as such in the Silurian region.

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CHAPTER IX.

ORGANIC REMAINS OF THE LOWER SILURIAN ROCKS.

A FULL acquaintance with the Silurian fossils of the British Isles can be gained only by a study of the various works in which they have been successively described. Of these works, the first in which the fossils were classified and placed in their true geological position, is the 'Silurian System*;' the next is a Report on the Silurian fossils of Tyrone, by Colonel Portlock; a third, on the Silurian fossils of Ireland, by Professor M'Coy. Then follow various publications of the Government Geological Survey, particularly the volume on the Malvern and Abberley Hills, by Professor Phillips, and certain monographs, descriptive of both Lower and Upper Silurian forms, in the Decades of the Geological Survey, by the late Professor E. Forbes and Mr. Salter. Notices of these fossils have also been published by Mr. Sharpe and other writers in the volumes of the Quarterly Journal of the Geological Society of London; and a detailed description of the Upper Silurian brachiopods, by Mr. Davidson, has appeared in the Bulletin of the Geological Society of France. In the last memoir, nearly all the British species are figured and described. The same author has published, in the volumes of the Palæontographical Society, an able monograph, detailing the generic characters of all the Silurian brachiopods. Lastly, a most important addition has been recently made to our knowledge of the British fossils of this age through the publication, by Professor Sedgwick, on the fossils of the Woodwardian Museum of Cambridge. This work, to which references are often made in the present volume, contains elaborate descriptions of upwards of 300 species, by Professor M'Coy, with figures of the new forms.

The reader, who may consult these various works, will find that, whilst a marked division was at first particularly insisted on, by my-

* The shells of the 'Silurian System' were described by James de C. Sowerby, who had previously figured and described some of the species in his 'Mineral Conchology.' The latter were chiefly from the Wenlock limestone.

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self, as existing between the Lower and Upper Silurian, subsequent researches, extended over large areas, have shown that the two groups are much more closely knit together in one natural series than I formerly supposed; it being now well ascertained, as already explained, that a considerable number of characteristic fossils are common to the inferior and superior members of the system, and that the two are zoologically united through the intermediate 'Llandovery rocks.' In the course of the observations which follow, this generalization will be placed in a clearer point of view.

In the earlier chapters of this work, the fossils of the Longmynd rocks, Lingula zone, and the lower part of the Llandeilo strata, have been fully adverted to. In describing the succeeding formations, however, the characteristic species alone have been cited, and it is now desirable to give a more complete view of the general characters of the chief mass of the Lower Silurian fauna, or of the Llandeilo and Caradoc formations.

Among the organic remains of the Lower Silurian rocks, Graptolites have been already often alluded to, being a form of polypes characteristic exclusively of the Silurian era (see p. 64), and which must have inhabited a sea with a muddy bottom. Of those forms which specially mark the Lower Silurian rocks, the double graptolite (Diplograpsus), and the twin graptolite (Didymograpsus), are the most common in Britain. Diplograpsus pristis, p. 64, Foss. 11. f. 4, ranges from the base of the Llandeilo flags to the Caradoc sandstone inclusive; D. folium, ib. f. 6, is common in the anthracite beds of Scotland (as well as in the alum slates, or Lingula zone, of Sweden); and there are at least two other forms, including D. foliaceus, Pl. 1. f. 2, in Wales.

There is a curious half-branched species, Diplograpsus ramosus, Hall, figured Foss. 11. f. 7, which seems to lead off to the twin graptolite, Didymograpsus, of which we have several species in England. Of these, Didym. geminus of Hisinger has already been quoted, Foss. 8. f. 8. p. 50; and D. Murchisoni, Foss. 11. f. 9, is one of our commonest Welsh species. The N. American form, D. sextans of Hall, Foss. 11. f. 8, is found in the S. of Scotland; and there is yet another two-winged graptolite (probably the same as a Canadian species, D. caduceus, Salter) in the slates of Wexford.

Of the simpler forms, those with teeth on one side only of the branches, Rastrites and Graptolites, the former is abundant, as above cited, Chap. 3. p. 64, in North Britain, where also the Graptolites priodon, Pl. 12. f. 1, occurs in plenty, though not quite so low in the series. This last fossil ranges from the Lower Silurian to the Upper Ludlow rock.

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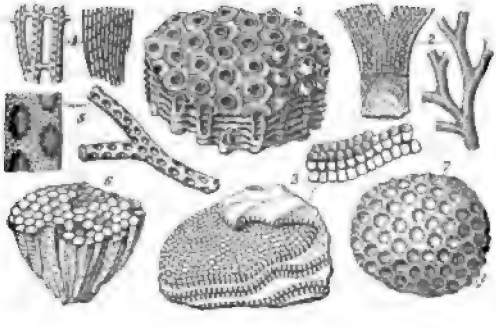
Opinion has been divided among naturalists as to the true position of Graptolites in the animal kingdom. Of late they have been generally regarded either as zoophytes of the Alcyonarian order, or as belonging to the Bryozoa (Polyzoa). That they were of the latter group seems now rendered almost certain by the discovery of a form intermediate between them and the Fenestellæ next to be noticed.

This is the Graptopora (or Phyllograpsus, as it has been called by M. Angelin), which, as already noticed, p. 47, occurs in the Lingula flags of Wales and Shropshire. It combines with the shape and general characters of the net-like Bryozoa, the texture and the form of the cells of the graptolite, and may be regarded as a bundle of these animals united by processes into a reticulated cup. Some curiously complex branched forms of graptolites, discovered by Sir W. E. Logan in Canada, complete the chain of affinities between the Graptolites and the Fenestellidæ.

But besides these inhabitants of ancient muddy seas, which are, as before said, exclusively Silurian in all quarters of the globe, other forms of Bryozoa are seen even in the lower portion of these deposits, and they are abundant throughout the series. These were formerly confounded with the true corals, and in the eye of the field-geologist would still pass for such, though they are really low forms of mollusks, having even no distant affinities with the Brachiopoda! They are here united in the same woodcuts (Foss. 27 & 28) with the true corals.

FOSSILS (27). LOWER SILURIAN BRYOZOA AND ZOOPHYTES.



1. Fenestella subantiqua of D'Orb. 2. Ptilodictya acuta, Hall. 3. Nidulites favus, Salter. 4. Sarcinula (Syringophyllum, Milne-Edw. and Haime) organum, Linn.

5. Heliolites inordinatus, Lonsd. 6. Favosites Gothlandicus, Goldfuss. 7. Heliolites megastoma, M'Coy, a species with large cells, found in Pembrokeshire.

The species with a net-like form, Fenestella and Retepora, just referred to, though occasionally met with in Caradoc rocks, are not common as Lower Silurian forms. The most frequent are flat branched forms allied to the living Eschara of our coasts, and which are known by the name Ptilodictya, Lonsdale (Escharopora, Hall). P. dichotoma, Foss. 28. f. 5, and P. acuta, Foss. 27. f. 2, are common species, and occur low down in the series. The more expanded forms, P. explanata, M'Coy, and P. fucoides, M'Coy, are found rather in the upper portions

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of the true Caradoc strata in Wales. Here, too,—if not in a still higher series, or at the base of the Llandovery rocks,—the Fenestella subantiqua, D'Orb. (F. antiqua, Sil. Syst.), Foss. 27. f. 1, makes its appearance. There are also some other, both branched and encrusting forms, which occur in the higher Caradoc strata of Wales. Glauconome disticha, Foss. 48. f. 5, and Fenestella Milleri, f. 4, are Wenlock fossils, which are found in the calcareous Lower Silurian slates of Llansaintffraid Glyn Ceiriog in Denbighshire*.

Of the true corals, the most prevalent are certain species of the genera Halysites, Heliolites or Palæopora (Porites, Sil. Syst.), Stenopora, Favosites, and Petraia.

FOSSILS (28). LOWER SILURIAN BRYOZOA AND ZOOPHYTES.

1. Stenopora fibrosa, Goldf. 2. The same species, variety Lycoperdon, Hall. 3. Petraia subduplicata, M'Coy; rarely found in the Caradoc strata.

4. Halysites catenularius, Linn. 5. Ptilodictya dichotoma, Portlock. 6. Retepora Hisingeri, M'Coy; Caradoc rocks of Westmoreland.

One of the most striking of these bodies, which ranges into and abounds in the Upper Silurian, and is widely spread through various countries, is the Halysites catenularius of Linnæus, Foss. 28. f. 4, the well-known 'chain-coral' (Catenipora escharoides of the 'Silurian System'). Another, still more abundant in the lower rocks, is the Stenopora (Favosites) fibrosa, both branched, f. 1, and hemispherical, f. 2. The Petraia subduplicata, f. 3, is but rarely found below the horizon of the Llandovery rocks: P. rugosa, Phill., and P. æquisulcata, M'Coy, are, however, not unfrequent Caradoc species.

Others, less common, are the Stromatopora striatella, Chap. 10, Foss. 50; Heliolites (Porites) interstinctus, p. 132, Foss. 18; H. inordinatus, Foss. 27. f. 5; H. megastoma, f. 7. Both these last are plentiful at Robeston Wathen in Pembrokeshire. The Heliolites petalliformis, Chap. 6, Foss. 18. f. 2, and H. tubulatus, ib. f. 1, have also been quoted by M'Coy from the Caradoc rocks of Westmoreland: H. favosus of the same author is a rare Lower Silurian species from Ayrshire. We have also Favosites Gothlandicus, Foss. 27. f. 6; F. alveolaris, p. 132, Foss. 17; and the Sarcinula (or Syringophyllum) organum, Linn., Foss. 27. f. 4,

* The curious fossil figured in Foss. 27. f. 3, Nidulites favus, belongs truly to the Llandovery rocks, and will be noticed under them. It appears to be far more nearly like the Bryozoa than any true coral; yet the size of the cells is gigantic for that group. It may even be the nidus of a gasteropod.

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found in the slates of Westmoreland, and in the Upper Silurian limestone of Gothland in Sweden. Nebulipora of Professor M'Coy, a new genus, contains two or three species of minute-celled corals, resembling Favosites, and is chiefly Lower Silurian. One, the Nebulipora favulosa of Phillips, figured in the woodcut, p. 55, Foss. 10. f. 22, is very common in the Llandeilo flags; and a variety of it, Nebulipora lens, M'Coy, is one of the most characteristic Caradoc fossils, p. 74: N. papillata, M'Coy, is both a Lower and an Upper Silurian fossil.

The reader has before him in these woodcuts a few only of the corals which most frequently occur in Lower Silurian strata; but if he wishes to study many other forms of these fossils, particularly those in the Upper Silurian rocks, where corals are much more abundant, he must consult the clear and faithful descriptions of them given by Mr. Lonsdale in the 'Silurian System,' in which work 62 species are accurately figured*. By reference to the authority of that valued friend, who assisted me so materially in preparing my original volumes, and to the works above cited, it will be seen that, of the seventeen or eighteen species here mentioned as found in the Lower Silurian, no less than eight, including the chain-coral, the Favosites alveolaris and F. Gothlandicus, the species of Heliolites, and the Stromatopora striatella, are still more abundant in the upper division of the system.

Of Crinoids, or the lily-shaped tenants of the deep, most of which were attached by their root or base to submarine rocks, the inferior strata of the Silurian epoch have in general afforded fragments only. Referring the reader therefore to the Plates 13–15 of this work, as containing the forms best known in the Silurian rocks when my work was published, it is enough now to state, that, for the most part, broken portions of the stems only of Encrinites have been detected in the earlier portion of these deposits in Britain.

One brilliant exception, however, is the Glyptocrinus basalis, M'Coy, a crinoid found in the Lower Silurian slates of North Wales; fine spe-

* The paleontologist will also naturally consult the writings of Milne-Edwards and Jules Haime, Archives du Muséum d'Histoire Naturelle, vol. v., who have shown that several of the corals which were supposed to be common to the Silurian and Devonian systems are not identical. See their monograph in the publications of the Palæontograph. Society, 1854. I must also specially refer the naturalist to Dana's magnificent work on Zoophytes, recently published as part of the results of the 'United States Exploring Expedition;' and to the descriptions and figures of Professor M'Coy, in Professor Sedgwick's work, Descript. Brit. Pal. Foss. of the Woodwardian Museum.

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cimens of it are to be seen in the Museum of Practical Geology in Jermyn Street, and in the Woodwardian collection at Cambridge; and there is a species or two in the Llandeilo flags of Shelve, Shropshire.

FOSSILS (29).

Glyptocrinus basalis, M'Coy. A Lower Silurian crinoid.

Next in order come those remarkable animals, whose globular forms and strong external plates have often enabled them to resist destruction better than the delicately constructed and slender-stemmed Encrinites:—these are the Sphæronites of old authors. They are the Cystidea of Von Buch. Abounding in the Lower Silurian of Scandinavia and Russia, they were long ago described by Linnæus and Gyllenberg, whilst they have had much new light thrown on their natural affinities by Von Buch, Volborth, the Duc de Leuchtenberg, and Edward Forbes. They constituted, in the primeval era, the representatives of the sea-urchins or Echinidæ of the secondary and tertiary periods and of the present day. They have affinity with Crinoids on the one hand (some possessing very perfectly formed arms and tentacles) and with sea-urchins on the other*, and have been divided into genera called Echinosphærites, Caryocystites, Sycocystites, Hemicosmites, Cryptocrinites, &c., some of which are here figured†.

They usually occur in clusters, on the shaly surface of beds of limestone, resembling bunches of enormous grapes; and in Sweden and Russia, where thus developed, they are associated with Orthidæ and other shells of the Lower Silurian rocks. In Britain they had not been found when the Silurian classification was published; but by the researches of the Government Surveyors they have been detected, and pretty plentifully, in strata first described by me as Llandeilo flag, at

* The views expressed in the text are those of Edward Forbes. The Cystidea, at least several of them, have a close affinity with the Pentremites of the mountain limestone.

† Other forms of these Cystidea are given in the work, 'Russia and the Ural Mountains,' vol. ii. See also Von Buch, 'über Cystideen,' Trans. Berlin. Acad. 1845; Volborth, 'über die Echino-Encrinen,' Bull. Sc. Acad. St. Petersburg, t. x., and Bull. Phys. Math., ib. t. iii. No. 6; Beschr. Thier. Silur. Kalk. v. Max. Herz. v. Leuchtenberg, St. Petersb. 1843; and E. Forbes, Mem. Geol. Surv. 1848, vol. ii. pl. 2.

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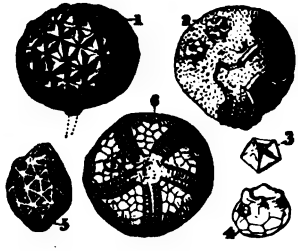
Sholeshook, Pembrokeshire (see p. 68); strata now known to belong to the Caradoc or Bala rocks. Indeed, in Britain they are not observed to occur lower down in the series; although, in Bohemia, some species are found in rocks of the age of the Lingula flags.

The usual forms in our country are species of Echinosphærites and Caryocystites. Echinosphærites aurantium, the commonest species in the north of Europe, is rare in Britain; but E. Balticus, Foss. 30. f. 1, and Caryocystites granatum, f. 5, both of them frequent in the Lower Silurian of Scandinavia, are found profusely in my old fossil-bearing locality of Sholeshook in Pembrokeshire; and thus our British Silurians are well paralleled with their foreign analogues. Echinosphærites arachnoideus, Forbes, occurs with them, and Caryocystites Litchi, Forbes, a globular species covered over with pores placed in pairs, and having five protuberances round the mouth. Echinosphærites punctatus, f. 2, and Caryocystites munitus, f. 4, are common species at Bala; and a fine species

FOSSILS (30). LOWER SILURIAN CYSTIDEANS.



1. Echinosphærites Balticus, Eichw. 2. E. punctatus, Forbes. 3. Ovarian pyramid of E. granulatus, M'Coy.

4. Caryocystites munitus, Forbes. 5. C. granatum, Wahl. 6. Agelacrinites Buchianus, Forbes.

of Glyptocystites, a genus which has the two halves of the cup differently constructed, has been found in the Lower Silurian shales near Llandovery. One exceedingly rare and curious form, belonging to a different group from the others, and more resembling the Silurian genus Pseudocrinites in its structure, possesses arms, which are affixed like the spokes of a wheel on the upper surface. It has been found in North Wales, and is figured in the Memoirs of the Geological Survey; it is represented above, f. 6. Professor E. Forbes named this form Agelacrinites Buchianus, in honour of that great geologist, the late Leopold Von Buch.

Of starfish two species were discovered in 1844 by Professor Sedgwick and Mr. Salter at Bala. One of these, Foss. 31. f. 1, described by the late Edward Forbes*, was thought by him to belong to the modern genus Uraster, so common on our own shores; it appears, however, to be distinct, and has been lately named Palæaster†; the other was un-

* Memoirs Geol. Survey, Decade 1.

† Ann. and Mag. Nat. Hist. for Nov. 1857; Rep. Brit. Assoc. 1856, Trans. Sect. p. 76.

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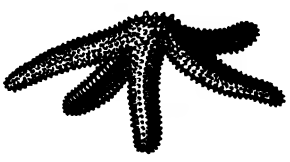
fortunately lost when it had been ascertained to belong to the true Ophiuroid group, and named provisionally O. Salteri, by Professor Sedgwick. It is probably a Protaster (see Chap. 7. p. 141).

FOSSILS (31). LOWER SILURIAN STARFISHES.

1

1. Palæaster (Uraster) obtusus, Forbes. Bala and Waterford.

2



2. P. asperrimus, Salter. A new species found near Welshpool.

The Palæaster obtusus has since been obtained from the slates of Wales and Ireland, and is represented in the preceding woodcut, together with a new and very distinct species from near Welshpool—the P. asperrimus.

Among the shells of the mass of the Lower Silurian strata, above the lowest or primordial zone, Lingulæ again occur, though of different species. The Lingula attenuata, Pl. 5. f. 1, is indeed one of the most characteristic shells of the Llandeilo formation, occurring plentifully at Builth and Llandeilo, in South Wales, and at Shelve, in Shropshire. Other species will be mentioned afterwards.

But by far the most abundant bivalve shells of these rocks belong to the group of brachiopods represented more particularly by the genera Orthis, Leptæna, and Strophomena. With these are associated, but much more rarely, some forms of Terebratula, or rather Rhynchonella. The genus Atrypa, as well as Pentamerus, has often been quoted from the Lower Silurian, but, as will be presently shown, the various species of these last two genera are almost exclusively found in the middle and upper portions of the system.

Although all the well-established forms which were known at the period of the publication of the 'Silurian System' are now reproduced from the original etchings in the annexed Plates (5, 6), attention will here be specially directed only to the figures of those which are found in abundance, and are therefore useful indicators, either as characterizing one zone or band of strata, or which, being found to ascend through a number of beds, show therefore that they lived through a long period of primeval time.

The genus Orthis is one of the most prolific forms of the brachiopods of this period. The species have generally one valve convex, the other flat, and are of a roundish outline. Those which most characterize the Lower Silurian are arranged, as before said, in Plates 5 and 6. Some are figured in the two following woodcuts.

The species which are abundant in the great mass of the Llandeilo

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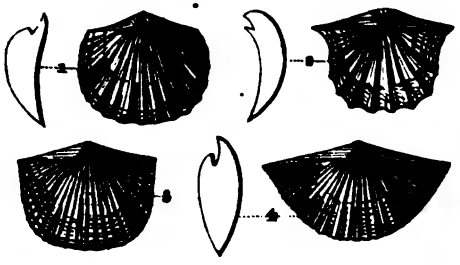
flags and Caradoc sandstone are the following:—Orthis elegantula, Pl. 5. f. 5; O. testudinaria, Pl. 5. f. 1, 2; O. vespertilio, Pl. 6. f. 2, 3; and the simple-plaited species figured in the following woodcut, Foss. 32, viz. O. flabellulum, f. 1; O. Actoniæ, f. 2; and the variable O. calligramma (virgata, Sil. Syst.), f. 3, 4.

FOSSILS (32). LOWER SILURIAN BRACHIOPODS.



1. Orthis flabellulum. 2. O. Actoniæ. 3, 4. O. calligramma, Dalman; two varieties.

Characteristic Lower Silurian forms of simple-plaited Orthides.

Among other species frequent in the lower division, and, as far as I know, peculiar to it, are the O. insularis, Pander, not here figured*; O. alternata, Pl. 6. f. 5; O. confinis, Salter; O. striatula, Emmons, Foss. 33. f. 3, not published in the 'Silurian System,' but still a very common British species, and the most abundant Orthis of this epoch in North America.

O. porcata, O. turgida, O. sagittifera, and O. Hirnantensis, described by M'Coy, are other species of the Lower Silurian, found in Wales.

Wherever several of these forms of Orthis are found, the geologist may be pretty sure that he is working in Lower Silurian rocks; and among these species it should be noted, that the Orthis Actoniæ, the more simple-ribbed varieties of O. calligramma, and particularly the O. striatula just mentioned, are the characteristic Llandeilo species; while O. vespertilio and O. flabellulum are very common in the Caradoc sandstone. There is not much difference in the distribution of these common brachiopods in the two groups of rocks, except as regards their proportionate numbers in each; but most of the other species above mentioned do not range lower than the Caradoc formation, while O. elegantula and O. calligramma occur in the Upper Silurian,—the former abundantly.

Five of the above species at least, the O. insularis, O. testudinaria, O. elegantula, O. calligramma, and O. biforata or lynx (formerly called Spirifer lynx), Foss. 33. f. 4, are quite common in the Lower Silurian of North America, Russia, and Sweden; and are everywhere abundant

* This common and characteristic species ought to have been introduced in the woodcuts. A good figure of it will be found in the Geol. of Russia, vol. ii. pl. 8. f. 7. A much rarer fossil, the Porambonites intercedens, which is known under several names in Dr. Pander's work, has been described by Prof. M'Coy from the Lower Silurian beds of the Wrae Quarry, Peeblesshire.

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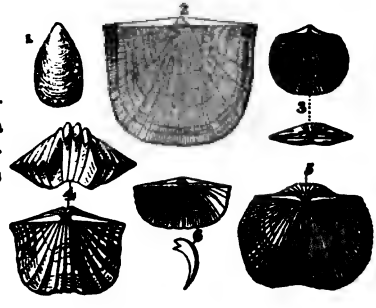
in those British localities originally defined by me as Lower Silurian, as well as in North Wales and Ireland. The last-named two species occur, though rarely, in the Wenlock limestone of Britain. The same is the case with O. porcata, M'Coy, Foss. 33. f. 5, which has lately been found in that limestone at Dudley. In the Western States of America this shell is known under various names. It is the O. occidentalis of Hall's work, but had been previously described, though from indifferent specimens, by M'Coy. This shell is one of our most characteristic Lower Silurian (Caradoc) types. The Orthis biloba of Linnæus (Spirifer sinuatus, Sil. Syst.), Pl. 20. f. 14, which is abundant in Wenlock shale, has been detected in the Lower Silurian rocks of S. Wales, and at the Chair of Kildare, Ireland.

FOSSILS (33). LOWER SILURIAN BRACHIOPODS.



1. Lingula attenuata. 2. Strophomena expansa, upper or dorsal valve. 3. Orthis striatula, Emmons.

4. O. biforata, Schlotheim. 5. O. porcata, M'Coy. 6. Leptæna sericea.

The closely allied genus Strophomena, consisting chiefly of the flatter forms of the so-called Orthis in the 'Silurian System,' exhibits some very marked and frequent species which are eminently typical of the Lower Silurian. These are, Strophomena expansa, Pl. 6. f. 4, and Foss. 33. f. 2; S. tenuistriata, p. 74, Foss. 12. f. 8; S. grandis, Pl. 6. f. 6, 7, which abound in the Lower Silurian rocks, and have been formerly given in the plates of my work, as species of Orthis and Leptæna; they not only prevail in the Llandeilo and Bala deposits of Wales, but are common in the strata of the same age in Westmoreland, and in the Caradoc sandstone of Shropshire.

Strophomena corrugata, Portlock, is a highly ornamental species of the genus, with radiating lines and transverse undulations; it is found in Wales and Ireland. Another shell, probably of this genus, and frequent at Bala, is the common Caradoc species, S. spiriferoides, M'Coy, Foss. 34. f. 2, which is so like Spirifer radiatus of the Upper Silurian rocks, as to be easily mistaken for it.

The universally spread Leptæna depressa (Sil. Syst.), now more correctly referred to the genus Strophomena, extends upwards throughout

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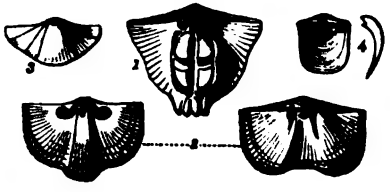
the whole series, from the oldest Llandeilo beds to the Upper Ludlow rock.

Of the two species of Leptæna which are prevalent in the lower division, the most frequent is L. sericea, Pl. 5. f. 14, and Foss. 33. f. 6, which, occurring in swarms among the slates of Snowdon, is also most abundant and characteristic in the Caradoc sandstone of Shropshire; whilst the L. transversalis, Pl. 20. f. 17, published originally as a fossil of the Wenlock shale, is now found in the Caradoc formation of Wales and Westmoreland. The former of the two last-mentioned species has indeed a universal range; being known in Russia, Scandinavia, Central Germany,

FOSSILS (34). LOWER SILURIAN BRACHIOPODS.



1. Orthis biforata, Schlotheim (internal cast). 2. Strophomena spiriferoides, M'Coy. 3. Leptæna quinquecostata, id. 4. Leptæna tenuicincta, id.; and a lateral view of the same.

the British Isles, and America. Leptæna tenuicincta, Foss. 34. f. 4, and L. quinquecostata, f. 3, are not unfrequent Caradoc species both in England and Ireland: the latter is found deep down in the Llandeilo flags.

The Orbiculoid and Cranioid groups, though not common in the lower division, yet afford some characteristic species. The remarkable Crania (Pseudocrania) divaricata, Foss. 35. f. 2, like its congener the Crania antiquissima (Pander) of Russia, is a Lower Silurian species. Discina (Orbicula) punctata of the Caradoc sandstone, f. 1, can with difficulty be distinguished from the beautiful D. cancellata, Sow., of the Trenton limestone, America; and Siphonotreta micula, f. 3, a small species of a genus which is abundant in the Lower Silurian beds of Russia, is found plentifully in the trilobite flags of Builth*.

Lingula, on the other hand, offers some prevailing forms. Such is L.

* As an example of the confusion which might be introduced by substituting the word Cambrian for Lower Silurian, it may be mentioned, that this species of brachiopod, though collected in my oldest and best-known Lower Silurian locality of Llandeilo flags at Builth, has been published as a Cambrian fossil in the second fasciculus of the Paleozoic Fossils of the Cambridge Museum. The reader must, indeed, be told, that very many of the fossils to which the words Bala and Cambrian are prefixed in that work descriptive of the Cambridge Museum, and published in 1851–53, have been alone found in my original Llandeilo and Caradoc rocks; the organic remains having been described by me between the years 1833 and 1839. Such are all those fossils from the Carmarthenshire localities of Llandeilo, Mandinam, Golengoed, Llangadoc, Noeth Grüg; all the Brecknock and Radnorshire localities, near Builth and Llandrindod; the Montgomeryshire localities, near Welshpool and Meifod, and at Allt-yr-Anker; Caradoc fossils from the west of Shropshire, &c.

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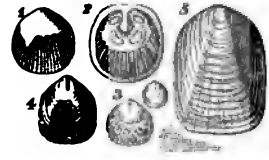
attenuata, the characteristic Llandeilo fossil before alluded to, in p. 55, 56. Its associates are, L. granulata, Foss. 35. f. 4, and a number of unpublished species: L. ovata, M'Coy, and L. tenuigranulata, f. 5, here figured,

FOSSILS (35). LOWER SILURIAN BRACHIOPODS.



1. Discina punctata. 2. Crania divaricata, M'Coy. 3. Siphonotreta micula, M'Coy; young and full grown, natural size. 4. Lingula granulata, Phill. 5. L. tenuigranulata, M'Coy; the largest fossil species of Lingula known in Britain; with a portion nat. size.

are conspicuous Caradoc species. Obolus, a genus closely allied to Lingula, is common in Russia; and, though not found in our Lower, is now known to be present in our Upper Silurian*.

The primeval forms allied to the genus Terebratula are now referred to the genus Rhynchonella of Fischer. This genus is very much less frequent in the lower than in the upper division of the system. Some few forms of it were described in the 'Silurian System,' which chiefly belong to the Llandovery rocks, and will be noticed under that head. One or two plaited species are known to occur in the Caradoc beds of Snowdon, and in the rocks near St. David's, Pembrokeshire, which are of Llandeilo age. Similar species, too, are found in Tyrone, and have been described by Colonel Portlock. A few smooth species, like Rhynchonella navicula, Pl. 22. f. 12, but not identical with it, are found in the Bala limestone. R. depressa, Pl. 22. f. 17, and R. rotunda, f. 18, originally described from the Upper Silurian, are said by Prof. M'Coy to occur in true Lower Silurian strata.

The genus Atrypa, so often quoted in paleontological works, is now restricted, and includes only those shells which have calcareous spires within, and a small area beneath the beak pierced by a round foramen. Thus limited, it contains only a few species, and these are most abundant in all the Upper Silurian strata, and in the Llandovery rocks. The A. marginalis of Dalman is the only one known with certainty to occur in the Caradoc sandstone, and it is found in many localities in Wales and Ireland.

Of the next great class, the Lamellibranchiata, or ordinary bivalve shells, a few only had been discovered in the lower group of strata when my large work was published. They are now, however, ascertained to be far from rare in the more arenaceous parts of the Caradoc strata in England; and they also occur in rocks of the same age in America. The genus Pterinea (Avicula, Sil. Syst.), so common, as will hereafter appear, in the upper division, has some representatives in the lower. P. pleuroptera,

* Davidson's Monograph of the Brachiopoda, Palæont. Soc. 1854, p. 136.

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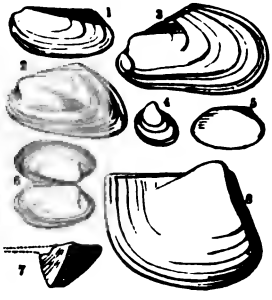
Conrad, and P. tenuistriata, Chap. 10, are two species of this formation, quoted by M'Coy as ranging upwards to the Ludlow rock. It is probable that some other species of the genus have an equal range.

There appear to be some species of true Aviculæ, and there are several examples of that section, or rather of that distinct genus Ambonychia, Hall, which has both valves gibbous and the anterior ear almost obsolete. These shells have been sometimes called Inoceramus, but have no affinity with that group. Ambonychia Triton, Foss. 36. f. 8, for example, is found at Llandeilo, and Colonel Portlock describes Amb. transversa and A. trigona, from the rich deposits of Tyrone.

FOSSILS (36). LAMELLIBRANCHIATA.



1. Modiolopsis postlineata, M'Coy. 2. M. expansa, Portlock. 3. M. modiolaris, Conrad. 4. Ctenodonta (Nucula) varicosa, Salter. 6. C. (Nucula) obliqua, Portlock. 5. Lyrodesma plana, Conrad. 7. Pleurorhynchus dipterus, Salter. 8. Avicula (Ambonychia) Triton, id.

Modiolopsis, Hall, is a still more common genus in the Lower Silurian. M. orbicularis, Pl. 7. f. 1, one of the few species published in my former work, is at present known only in the Caradoc sandstone of Shropshire; it was formerly described as an Avicula. M. modiolaris, Foss. 36. f. 3, and M. postlineata, f. 1, are frequent in the Caradoc rocks of North Wales, where M. inflata, M'Coy, and some others, are also occasionally met with. M. expansa, f. 2, is a flattish species found in strata of the same age in Ireland, and several large and rounded forms occur with it. The genus is closely allied to the common Modiola, or mussel, of our coasts.

Nuculæ and shells of similar genera with toothed hinges are not scarce; but few of them have been yet described. It is well, however, to note, that the small triangular species, Nucula (Ctenodonta) varicosa, Foss. 36. f. 4, and N. obliqua, f. 6, are frequent in the lower division,—the former in Wales, the latter in N. Ireland. It is most probable that these so-called Nuculæ are all referable to a distinct genus, Ctenodonta (Tellinomya, Hall), Rep. Brit. Assoc. 1851, Sect. p. 63, which, like the Isoarca of Münster, has the ligament external. Lyrodesma plana, Foss. 36. f. 5, which belongs to the same group of shells, is found in the limestone at Bala.

The Orthonota (Cypricardia of the Sil. Syst.) is a genus more frequently met with in Upper Silurian rocks, but some are Lower Silurian.

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O. nasuta occurs in the Caradoc of Horderley, and is represented in the woodcut, Foss. 12. f. 12. Cardiola is rare, but not wholly absent. In the illustration on the preceding page, a rare fossil is figured, Pleurorhynchus dipterus, f. 7, which, though unknown in England and Wales, has been found by Mr. J. Carrick Moore in the Lower Silurian rocks of Ayrshire, and by the Government geologists at the Chair of Kildare, in Ireland. To these may be added a remarkable genus lately found in Montgomeryshire, the Megalomus of Hall. It is a thick and clumsy shell, something like the Megalodon of the Devonian rocks, but with less defined teeth. Hall's species is from the Clinton group (Llandovery rocks); the British one is from the true Lower Silurian at Horderley.

The Gasteropods, or univalves of the most ancient natural system of life, are now declared by naturalists to belong mainly to genera which are extinct. Such is the Murchisonia of d'Archiac and de Verneuil, formerly included in the genus Pleurotomaria. Such also are Holopea and Raphistoma of the American paleontologists, Loxonema and Macrocheilus of Phillips, and Euomphalus. A few species of Turritella, indeed, are quoted; but these in all probability belong to a different genus, the Holopella of M'Coy.

It is important to remark, that certain shells which abound in the younger secondary and tertiary deposits, and at the present day, viz. the true species of Trochus, Nerita, Pleurotoma, and Buccinum, have not yet been found in these ancient rocks*. Some few recent genera of Gasteropods, however, must still be quoted, such as Turbo, a small Natica? or Pileopsis, and Patella. Of the latter genus, an Irish species (the P. Saturni, Goldfuss?) is here figured, Foss. 37. f. 9.

The families which appear to have existed during the Lower Silurian time were—Littorinidæ, Pyramidellidæ, in abundance, with Haliotidæ, and a rare Patella. Chitons first appear in the Llandovery strata.

In the Upper Silurian the true Turbinidæ (Euomphalus), with Calyptræidæ (Pileopsis and some allied genera). The Naticidæ seem to have commenced in the Devonian period.

Among the old genera, the genus Euomphalus is of very early creation,

* The reader may be surprised to find numerous species of the four last-mentioned genera spoken of in the original 'Silurian System;' but it is only of late years that the distinctions have been drawn, by which such genera have been excluded from the Silurian rocks, and the accuracy of the exclusion is now agreed upon by most naturalists, although these shells have much the external appearance of the above-mentioned genera. Euomphalus is probably a very near ally of the modern genus Delphinula: it occasionally preserves its operculum and even the nacreous lustre of its interior. These changes, made by paleontologists in the generic names, have an important bearing on the philosophy of the science, as the determination of the correct affinities of these fossils may lead us to understand the conditions under which they lived; it having been shown conclusively by the late eminent Professor Ed. Forbes, that certain conditions of depth and of sea-bottom were essential to the presence of one group of animals, while another assemblage might be indifferent to them.

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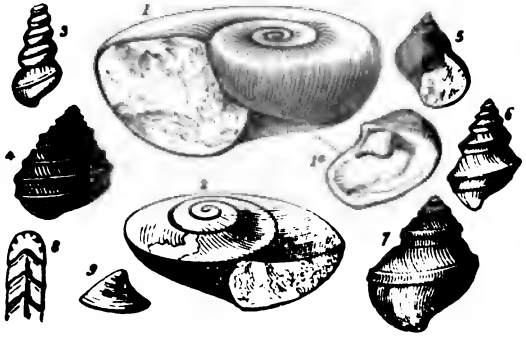
four or five species being known in the inferior strata (one or two are figured in Pl. 7). We find that Euomphalus, like many other genera, pervades the whole Silurian system; but it is far less characteristic of the Lower than of the Upper Silurian. It is not certain that any one species extends upwards from the Llandeilo flags into Wenlock strata.

FOSSILS (37). GASTEROPODA.



1. Maclurea Logani, Salter?, from the Lower Silurian of Ayrshire; operculum (from Canada), f. 1 *a*. 2. Raphistoma—sp. undescribed. 3. Murchisonia obscura, Portl. 4. Turbo? rupestris, Eichw. 5. Holopea concinna, M'Coy. 6. Murchisonia gyrogonia, M'Coy. 7. M. semirotundata, Portl. 8. Helminthochiton Griffithii, Salter. 9. Patella Saturni, Goldfuss?

One of the most emblematic univalves of this age is the Murchisonia, more complete specimens of which are now given, in the annexed woodcut, Foss. 37. f. 6, 7, than any figured in my former work, where they were called Pleurotomariæ. In Portlock's Report several species of this genus are described from the Lower Silurian rocks of Tyrone: one of these, M. turrita, Portl., is very elegantly sculptured; another, M. semirotundata, Foss. 37. f. 7, is conspicuous for its broad rough band. M. gyrogonia, f. 6, and M. simplex, M'Coy, are common in Wales, and there are many other similar species. Turritella is absent. The Lower Silurian shells resembling it are either smooth forms of Murchisonia, such as M. obscura, Foss. 37. f. 3, in which case they show the characteristic band, or they belong to the newly proposed genus Holopella, in which the striæ of growth run straight across the whorls, and are not bent into a notched or angular form. Several of the latter genus have been described from the Llandovery rocks, but they are comparatively rare in the Caradoc or Llandeilo flags. They have in general an elongated and beaded shape, resembling the above-quoted Murchisonia obscura. Trochus lenticularis of the 'Sil. Syst.,' Pl. 10. f. 2, and several similar discoid and angular univalves, are now referred to the genus Raphistoma, Hall. This genus is exceedingly common in the Lower Silurian rocks of America; it also occurs in Scandinavia and Russia; a species of it found at Llandeilo is here given, Foss. 37. f. 2, and others are known in the Silurian rocks of the S. of Scotland and in Tyrone.

Holopea, Hall, though rather an obscure genus of smooth rounded univalves, must now include many Lower Silurian species. One is

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figured in Pl. 7. f. 4, as H. striatella (Littorina, Sil. Syst.); another, H. concinna, is represented here, Foss. 37. f. 5.

Other shells, still provisionally called Turbo, *e. g.* T. rupestris, f. 4, and T. sulcifer, Eichw., T. crebristria, M'Coy, &c., may probably belong to an extinct genus allied to Holopea (Cyclonema of Hall). Turbo rupestris occurs in the Lower Silurian limestones of Ireland, and often still retains the coloured bands that decorated the shell when alive. This feature will be dwelt upon in the concluding chapter, as limiting the depth of water at which such shells lived.

Though not yet detected in England or Wales, Maclurea (Hall), a characteristic genus of the Lower Silurian rocks of North America, has been found in strata of the same age in Scotland. The shell (Foss. 37. f. 1) appears to be sinistral or reversed, the top flattish, and the base umbilicate. In all probability, however, it should be viewed the other way upwards, and so appear with a sunken or concealed spire. Its mouth is closed by a remarkable operculum, of which f. 1 *a* shows the inner side. I collected a species of this genus in the Lower Silurian strata of Ayrshire, associated with Orthides, trilobites of the genus Asaphus, and other Lower Silurian fossils. A Canadian species, approaching to M. magna of the United States of North America, and named by Mr. Salter, Maclurea Logani, after the able geologist who discovered it in Canada, is the form to which our British fossil is most allied. The operculum figured (Foss. 37. f. 1*a*) is from that species.

In speaking of the altered limestones and quartz rocks of Lower Silurian age at Durness, in Sutherland, a large Maclurea was mentioned (p. 196) as being distinct from any form yet described. The nature of this shell seemed so obscure when the specimens first obtained were examined, that it could scarcely be decided whether it might not be a Euomphalus or Raphistoma. The specimens last detected, one of which is here drawn, have, however, proved beyond a doubt, that the Durness fossil belongs to the true Lower Silurian genus Maclurea. The upper surface of the shell is shown in Foss. 38. f. 1, and its lower surface in f. 2. The species differs from the M. magna, Hall, of N. America, in the slight convexity of the whorls beneath, and from M. Logani of Ayrshire, Foss. 37, by the greater number of turns of the spire. The operculum, Foss. 38. f. 3, is of a most peculiar form, as may be seen by comparing it with that of M. Logani, Foss. 37. f. 1*a*. It is almost spiral, and this greatly helps to strengthen the opinion of Mr. S. P. Woodward, that the genus may be one of the most ancient forms of the Rudista, a group not previously known to occur below the horizon of the Oolitic formations.

With this Maclurea, so decided in its bearing upon the age of the rocks in which it is imbedded, are associated other forms no less confirmatory of the identity of this group with the Lower Silurian rocks of

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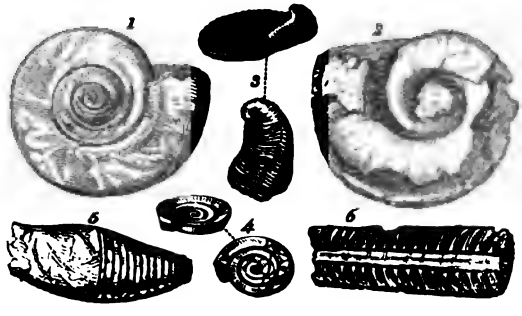
N. America. They are here grouped in the same woodcut, in order to explain at a glance the general fossil contents of these Highland rocks.

The Ophileta compacta, Foss. 38. f. 4, the smooth Orthoceratites with large compressed siphuncles, f. 6, others with an annulated surface, and a species of Oncoceras, f. 5, all closely resemble fossils of the Lower Silurian rocks of N. America, which range from the Calciferous rock up to

FOSSILS (38). LOWER SILURIAN SHELLS FROM THE NORTH-WESTERN HIGHLANDS.



1. Maclurea Peachii, n. sp., upper side. 2. The same, lower surface. 3. The long, twisted operculum; two views. 4. Ophileta compacta, Salter. 5. Oncoceras, sp. 6. Orthoceras, with compressed siphuncle, like a Canadian species.

the Trenton limestone, both inclusive. Thus, for example, although the Oncoceras, f. 5, is specifically distinct from any published American species*, yet, when taken with the forms above enumerated, and particularly with the Ophileta compacta, which is identical with a Canadian species, there can be no doubt that these Highland strata occupy the horizon assigned to them. The lower quartz rock of this group is characterized by abundant traces of a minute shelly annelide, Serpulites MacCullochii, which will be presently figured (see p. 222).

Bellerophon, a paleozoic form of the mollusks classed by some naturalists with Heteropoda, is one of those genera which specially link together the Lower and Upper Silurian divisions in one system of life. Thus, B. carinatus, Pl. 34. f. 8, and B. dilatatus, Foss. 39. f. 8, are common to both divisions, ranging from the Caradoc sandstone to the Ludlow rocks in Ireland and Wales. On the other hand, there are several species which as yet are known only in the lower division, and are very characteristic of it. B. acutus, Pl. 7. f. 8, B. bilobatus, figured in Chap. 4, Foss. 12. f. 10, and B. nodosus, f. 11, are among the common fossils of the lower part of the Caradoc sandstone. One of these species, the B. bilobatus, is equally characteristic of the same deposits in North America, Spain, and Bohemia. B. perturbatus, Foss. 39. f. 6 (Euomphalus, Sil. Syst.), is one of the common fossils of the black Llandeilo

* See Hall, Pal. New York, vol. i. pl. 41.

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slates of Wales. There are other less-known species, and some are yet unpublished.

Certain naturalists regard the genus Bellerophon as the shell of a cephalopodous animal, differing from the ordinary forms of that class in the want of septa or partitions within the shell. Although there is some ground for the supposition, these shells are usually believed to be Nucleobranchiata (or Heteropoda), allied to the floating Carinaria or glass-shell, which they much resemble both in form and sculpture.

The large Irish Lower Silurian fossil, Ecculiomphalus Bucklandi, Foss. 39. f. 5, may probably be compared with the modern genus Atlanta; if its thin shell, triangular section, and finely striated surface do not betray affinity with the group next mentioned.

There are certain genera, now clearly ascertained to be forms of Pteropoda—one of the inferior groups of mollusca. Of Conularia, for example, a most beautifully ornate form, there are two or three species in the Lower Silurian. C. elongata, figured in the next woodcut, Foss. 39. f. 3, is frequent in Ireland; and C. Sowerbii, Pl. 25. f. 10, ranges upwards from the Caradoc strata to the Ludlow rocks. M. Barrande has figured many curious forms of Conularia from the Silurian rocks of Bohemia, one of which is spirally curved. Theca, a genus exceedingly like the modern Clio, has two species at least in the lower division; viz. T. triangularis (Orthoceras of Portlock), Foss. 39. f. 2, and another species, f. 1 (the T. triangularis of Hall), to which Mr. Salter applies the name T. reversa. It is found in N. America, Scotland, and Wales, and is distinguished by having the dorsal, not the ventral surface, the convex one; otherwise it is much like T. Forbesii (Chap. 10).

FOSSILS (39). HETEROPOD AND PTEROPOD MOLLUSCA.

1. Theca reversa, Salter (dorsal view). 2. T. triangularis, Portl. (dorsal and ventral sides). 3. Conularia elongata, Portl. 4. Pterotheca transversa, Portlock. 5. Ecculiomphalus Bucklandi, Portl. 6. Bellerophon perturbatus. 7. B. acutus. 8. B. dilatatus.

Figs. 5 and 8 are species often 3 inches wide—the figures are much reduced.

Pterotheca is a new genus proposed (Report Brit. Assoc. 1852) for a wide shell like Cleodora;—P. transversa is here given, f. 4. P. undulata is a large and beautiful fossil found in N. Wales and Shropshire.

It is to be remarked, that these ancient specimens of their order were gigantic in comparison with their modern representatives.

Cephalopodous or chambered shells of the genera Orthoceras, Cyrto-

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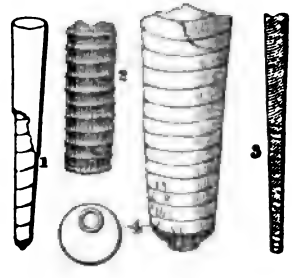
ceras, and Lituites occur in the Lower Silurian rocks. In the original Silurian region they are, indeed, less abundant in the lower than in the upper divisions of the system; but on the continent of Europe, particularly in Scandinavia, where they occur under different conditions, and in limestone, they are more frequent in the Lower than the Upper Silurian. Among the earlier developed British species are to be noted the Orthoceras politum, M'Coy, a large smooth shell seen by myself *in situ* in Ayrshire*; O. vagans, Foss. 40. f. 1; O. bilineatum, f. 2; O. tenuicinctum, f. 3: the latter is a beautiful fossil. Another species characteristic of the Lower Silurian strata, and having a large lateral siphuncle, is the O. Brongniarti of Portlock, f. 4; it is supposed to be identical with one from North America, where similar forms are common in the Lower Silurian rocks. The great Orthoceratite of the same strata of Scandinavia and Russia, O. vaginatum, Schlotheim, is occasionally three feet long; it has been found in Scotland†. Smooth Orthoceratites, on the contrary, with slender central siphuncles, are not confined to either the upper or lower division.

FOSSILS (40). CEPHALOPODA.



1. Orthoceras vagans, Salter. 2. O. bilineatum, Hall. 3. O. tenuicinctum, Portl. 4. O. Brongniarti, Portl.

(Some forms of Orthoceras most common in the Lower Silurian rocks.)

It must here be specially noted, that in the progress of research no less than eight species of Orthoceratites have been found in England, Wales, and Ireland to range from strata of the age of the Caradoc rocks to the Upper Silurian‡; several of them even into the Upper Ludlow rock: *e. g.* O. angulatum, Wahl. (O. virgatum, Sil. Syst.); O. ibex, Sil. Syst.; O. subannulatum, Münst.; O. annulatum, Sil. Syst. (O. undulatum of foreign authors); O. filosum, Sil. Syst.; O. subundulatum, Portl. (Criseis Sedgwicki, Forbes); O. tenuicinctum, Portl.; and O. primævum (Criseis primæva, Forbes). There are probably others which have as great a range§.

The singular O. bisiphonatum of the Sil. Syst., only found in one locality, near Llandovery in South Wales (Pl. 11. f. 5), appears to have

* See Quart. Journ. Geol. Soc. vol. vii. pl. 10. † Ibid. p. 177.
‡ Synopsis of the Paleozoic Fossils, Sedgwick and M'Coy, pp. 313, &c.
§ See Plates 26 to 29, and Chap. 10, for some of these species.

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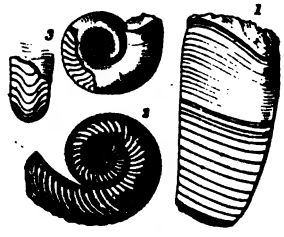
two siphuncles. It will be again noticed under the Llandovery formation. The species does not really belong to Orthoceras, and should form, in the opinion of Mr. Salter, a new genus, for which he proposes the name of Tretoceras. Oncoceras has been already mentioned, p. 217.

There are several species of the genus Lituites in these old strata. L. cornu-arietis, Foss. 41. f. 2, and L. Hibernicus, f. 3, are good examples of our British species. The former is also found in Scandinavia. L. anguiformis, Salter, is a third; and there are other species in the Llandovery rocks. Cyrtoceras, which is distinguished by being more slightly curved than Lituites, includes several species in Britain; one, C. inæquiseptum, from Ireland, is here represented, f. 1; and some others are figured by Portlock; and one of the Ayrshire cephalopods is probably the Cyrtoceras multicameratum, Hall, of the United States.

FOSSILS (41). CEPHALOPODS.



1. Cyrtoceras inæquiseptum, Portl. 2. Lituites cornu-arietis. 3. L. (Trocholites) Hibernicus, Salter.

Curved forms of Cephalopoda, rare in British Lower Silurian strata.

Annelides, or sea-worms, we have already seen, Chap. 2, prevailed in some of the earliest sediments in which traces of organic remains are found*. They were not less plentiful in succeeding periods of the Silurian epoch, and occurred both in the form of burrows in the strata (Scolites), and as tracks upon the surface (Helminthites, &c.). It is scarcely doubtful that most of the long sinuous tracks observable on these old sediments were made by wandering species of this tribe; but the idea has nevertheless been suggested by Geinitz, that some of those usually called Nereites may be soft and fleshy forms of Graptolithina, and therefore have no real affinity with the Annelides. Certain branched forms found in the old rocks of Thuringia, and described by Prof. Richter, give considerable force to this suggestion.

Specimens of these tracks were figured, as previously stated, from Llampeter, in South Wales, where they occur in strata which have been shown to overlie the Llandeilo rocks (see p. 79); *e. g.* Nereites Cambrensis, Foss. 42. f. 3; N. Sedgwicki, f. 2; and Myrianites M'Leayi, f. 1.

Another form of these creatures, Crossopodia Scotica, f. 4, is given from specimens collected by Professor Sedgwick, in the Graptolitic schists

* See Quart. Geol. Journ. vol. xii. p. 246; & vol. xiii. p. 199.

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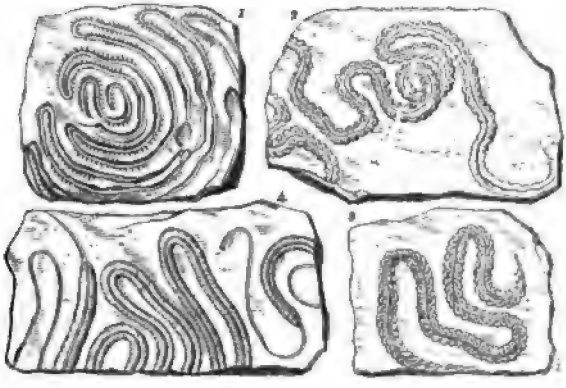
near Moffat, in Dumfriesshire, a locality which I have also examined, and where I found other species of these long sea-worms. The length of some of these creatures must have been prodigious, probably many yards, judging from the frequent parallel coils which are exhibited on the surface of the schists. (The annexed figures are very much reduced.) It should, however, be borne in mind, that in many cases we see only

FOSSILS (42). ANNELIDES; OR MARINE WORM-TRACKS*.



1. Myrianites MacLeayi, Sil. Syst. 2. Nereites Sedgwicki, ib. 3. N. Cambrensis, ib. 4. Crossopodia Scotica, M'Coy.

Tracks of sea-worms in fine muddy sediments, now altered into slates. S. Scotland and Wales. (The species figured in the 'Silurian System' were drawn on stone, and these figures could not therefore be repeated in the plates at the end of the volume.)

the track of the worm, and not the impression of its soft body, which could rarely be preserved. Such tracks as these are met with in all the paleozoic rocks, but the burrows of the worms (Scolites and Arenicolites) are yet more frequent. Wherever the sediments are sandy, these creatures seem to have been present, and the markings generally attributed to fucoids are for the most part only the filled-up burrows of marine worms.

The Tentaculites and Cornulites of the earlier primeval strata must also be mentioned as remains of animals of this order. They were worms with shelly tubes like those of Serpula, but distinguished easily by their annulated form and cellular structure† (see Pl. 16. f. 3–10, for the form and magnified sections). Tentaculites Anglicus, Pl. 1. f. 8, in Britain, is a characteristic Caradoc fossil, but is also found abundantly in the Llandovery rocks; (T. scalaris of the Sil. Syst. is the interior cast of it). Cornulites serpularius, Pl. 16. f. 3–10, is also a cosmopolite of this age, ranging from Sweden to North America; but, unlike the Tentaculite just mentioned, it ascends from the Lower Silurian strata, where it is rare, to the very summit of the Ludlow rocks.

* See Sil. Syst. pp. 363, 699, &c.

† These fossils, Tentaculites and Cornulites, have been assigned to various groups of animals, the notion that they were parts of crinoidal creatures being the most generally accepted. They were, however, shelly tubes, of a highly complex cellular structure, not jointed tentacles or stems; and could, by no means, be parts of such animals.—J.W.S.

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The minute Annelide before spoken of as abounding in the quartz rocks of the N.W. Highlands, is here figured. Although the tube is thicker in proportion than in any known species of Serpulites, it is here provisionally referred to that genus, and is named Serpulites MacCullochii, after the distinguished geologist who first noticed it (see p. 217)*.

FOSSILS (43). ANNELIDE TUBES FROM THE N.W. HIGHLANDS.

Small, thick, shelly tubes of annelides (Serpulites? MacCullochii).

Collected from the lower quartz rock of Durness, Sutherland, by Mr. C. Peach.

Crustaceans.—Nearly all the Articulata which have yet been detected in the Lower Silurian rocks belong to the extinct family of entomostracous crustaceans called Trilobites. The Silurian era was evidently one in which these animals flourished most; for they became infinitely less abundant in the Devonian, and expired before the close of the Carboniferous era, during the earlier part of which, as will hereafter be seen, very few of their genera prevailed. As already indicated, we find some forms of the Trilobite in the oldest accumulations in which animal remains occur†; and it is now to be remarked, that whilst, on the whole, certain genera and species of these creatures are more exact indicators of the successive strata than the other classes of animals, and that several genera are absolutely peculiar to the Lower Silurian rocks, there are some species that are widely diffused in strata of this era over the world, which are common to both divisions.

Of these there is perhaps no one species which has a greater vertical range, or is more widely diffused in geographical space, than the long-known Dudley fossil, Calymene Blumenbachii, Brongn. When this trilo-

* In thus naming these Annelide-tubes, justice is done to the scientific acumen of the late Dr. M'Culloch, who, desiring to indicate that the quartz rocks of Sutherland were metamorphic strata which had originally contained animal remains, suggested that the tubes might have been those of Orthoceratites.

Many persons (including Sedgwick and myself), who have since observed these minute fossils, could not believe that they were of animal origin; and, although M'Culloch erred in referring them to Orthoceratites, still it must be remembered that he was the first person who suggested that these crystalline rocks were at one time deposits in which marine creatures had been entombed.

† For example, in the Alum slates of Sweden (Regiones A. B. of Angelin), in the Lingula slates of N. Wales, and in the Lowest Silurian of the United States. This is the zone to which M. Barrande first attached importance (Zone primordiale), by working out its very peculiar and remarkable fauna in Bohemia.

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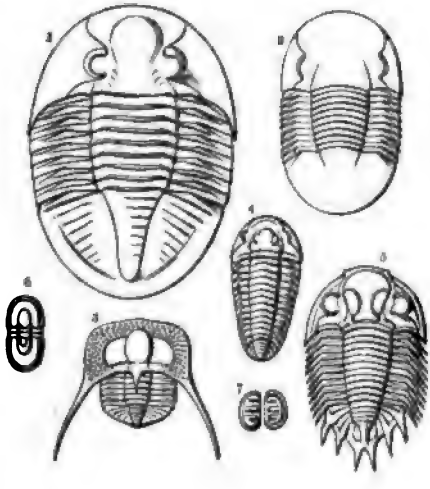
bite was described in the 'Silurian System,' it was considered to be typical of the upper rocks only, whether of Wenlock or of Ludlow age; but it has since been found in abundance in the lower strata of the Caradoc formation, even near Snowdon; and I have myself procured it from beds of Caradoc sandstone in Shropshire. Again, a variety of the true species occurs in the Lower Silurian rocks of Tyrone; and thus, like many examples of the other classes of marine animals which lived in primeval days, this crustacean links together the Lower and Upper Silurian in one system of life. (See Pl. 18. f. 10. The head is represented, Foss. 12. f. 1.) It has also been found in Sweden, Bohemia, North America, and Eastern Australia (?), and always in company with similar generic forms. Acidaspis Brightii, Pl. 18. f. 7, and the Cheirurus bimucronatus, Pl. 19. f. 11, also occur in both divisions; the former, however, but rarely, the latter abundantly. So do also the Cyphaspis megalops, Chap. 10, and Staurocephalus Murchisoni, Barr., a small trilobite with a globular head and serrate tail. The Lower Silurian fossil, Pl. 2. f. 3, 4, called Asaphus Vulcani in the 'Silurian System,' is probably a species of Homalonotus, a genus formerly thought to be peculiar to the Upper Silurian, but of which several examples are now known in the lower division.

FOSSILS (44). TRILOBITES TYPICAL OF THE LOWER SILURIAN ROCKS.



1. Asaphus Powisii. 2. Illænus Davisii, Salter. 3. Trinucleus concentricus, Eaton (Trin. Caractaci, Sil. Syst.). 4. Calymene brevicapitata, Portl. 5. Lichas laxatus, M'Coy. 6. Agnostus trinodus, Salter. 7. Beyrichia complicata, Salter, enlarged. (The last is not a trilobite, but a bivalved phyllopodous crustacean.)

The genera peculiar to the Lower Silurian, not only in this country, but on the Continent and in America, are:—Olenus, Agnostus, Paradoxides, Cybele, Trinucleus, Ogygia, Asaphus, Remopleurides, and the trilobed forms of Illænus; the first three being principally (though not wholly, except Paradoxides) confined to the lowest division or Lingula flags. On the other hand, the genera Ampyx, Calymene, Lichas,

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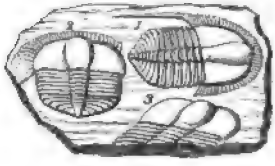
Proetus, Homalonotus, Cheirurus, Encrinurus, Bronteus, and that division of Illænus which I still believe to be a true genus* (Bumastus, Murch.), are found both in the Lower and Upper Silurian. Mr. Salter reminds me, further, that there is scarcely one genus of the upper division which had not previously existed in the earlier period.

The principal forms, however, which have proved unerring indices of the Lower Silurian of Britain, are the Olenus, Agnostus, and the true Asaphus, such as A. Powisii, Foss. 44. f. 1; A. tyrannus, Pl. 1. f. 4, 5, and Pl. 2. f. 1, with five species of Trinucleus, Pl. 4, all of which were formerly published as true Lower Silurian types.

The Trinucleus concentricus (Caractaci, Sil. Syst.), Pl. 4. f. 2–5, and Foss. 44. f. 3, has a very extensive Lower Silurian range, both in Europe and America. This species varies greatly in form and markings, and, being a very common species, it is met with in every variety of distortion and compression, so that it might often be divided into a number of different species.

FOSSILS (45).

TRINUCLEUS CONCENTRICUS: THREE SPECIMENS, DISTORTED BY SLATY CLEAVAGE.



In illustration of the various forms which a single species may assume under the influence of that crystalline change operated in the strata which is called slaty cleavage (see p. 31). The woodcut represents a group of forms, apparently very dissimilar, but all of the same species, here given in their natural position on a fragment of slate. (Phillips, Report Brit. Assoc. vol. xii. pp. 60, 61.)

The Trinucleus Murchisonii, Foss. 8. f. 7, together with the remarkable species T. Gibbsii, Foss. 9. f. 7, have already been described from the lowest beds. T. fimbriatus, Pl. 4. f. 7, and T. Lloydii, f. 6, are good indications of the Llandeilo flags, for they occur in them only; while T. seticornis, Hisinger, a species found in Wales, Scotland, Ireland, and also in Sweden, is, on the contrary, exclusively a Caradoc species (see p. 75).

Better specimens of some species of trilobites having been found than those which were collected at the time of the publication of the 'Silurian System,' figures of them are given in the following woodcut, Foss. 46: viz. Phacops conophthalmus, f. 3, and Ampyx (formerly Trinucleus) nudus, f. 7. Several species, not there described, have been since added to our lists, and a few of them are also here figured. Cybele verrucosa, f. 2, is one of these new fossils, and is a common species in Britain and

* The pygidium is simple, *not trilobed* as in most species of Illænus.

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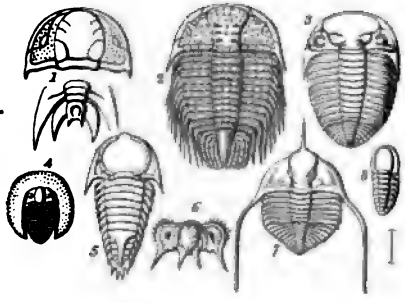
Sweden. C. rugosa, Portlock, Encrinurus baccatus of the same author, E. sexcostata, Salter, Harpes Flanagani, Foss. f. 4, and H. Dorani, Portl. (the latter both in Ireland and Wales) are all Caradoc or Bala species. Remopleurides dorsospinifer, f. 5, and three other species, Acidaspis bispinosus, f. 6, Cyphoniscus socialis, f. 8, and Cheirurus clavifrons, f. 1, common in Pembrokeshire and Ireland; Cheirurus gelasinosus, Portlock, in Scotland and N. Ireland, are now well-known species. Lichas Hibernicus, from Tyrone, and Lichas laxatus, Foss. 44. f. 5, are examples of a highly complex genus not known in a complete form when my former work was printed. Illænus Davisii, f. 2, with I. Bowmanni, Salter, from Bala, and I. Murchisoni, from Carmarthenshire, are common trilobites. Agnostus trinodus, f. 6, is a Caradoc fossil; the A. Maccoyi, Pl. 3. f. 7, from Builth, is from the Llandeilo flags. A. pisiformis, the Swedish species, has been already quoted, pp. 53, 104.

New species of Acidaspis from Shropshire, and several fine forms from the Girvan district of Shropshire have lately been figured by Prof. Wyville Thomson*, of Belfast, and Mr. Salter; and there are numerous species and even genera yet undescribed.

The minute bivalved crustacean of the phyllopod tribe, Beyrichia complicata, f. 7, occurs throughout the whole of the Lower Silurian region of Shropshire and Wales. Of this last-named genus several other forms are known; B. strangulata, Salter, is Lower Silurian; B. Klœdeni, M'Coy, B. siliqua, Jones†, &c., are Upper Silurian species. The genus Leperditia (composed of smooth forms of this group) also furnishes some British Silurian species‡; and one or two large fossils of the phyllopod group have also been lately collected in the black slates of the South of Scotland.

FOSSILS (46). LOWER SILURIAN TRILOBITES.



1. Cheirurus clavifrons, Dalm. 2. Cybele verrucosa, Dalm. 3. Phacops conophthalmus, Boeck. 4. Harpes Flanagani, Portl. 5. Remopleurides dorso-spinifer, Portl. 6. Acidaspis bispinosus, M'Coy. 7. Ampyx nudus. 8. Cyphoniscus socialis, Salter: the line beneath indicates its natural size.

No other tribes of crustaceans than the Trilobites, the few phyllopods above noted, and the decapod (?) crustacean, Hymenocaris vermicauda, mentioned in Chap. 3, have been found in the Lower Silurian rocks of

* Quart. Geol. Journ. vol. xiii. p. 206.
† Ann. & Mag. Nat. Hist. 1855, vol. xvi. pls. 5 & 6.
‡ Jones, Ann. & Mag. Nat. Hist. 1856, vol. xvii. p. 95.

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Britain. In the sequel it will be seen, that a group of Crustacea, vastly superior in size, but perhaps not of higher organization than those above cited, is found in the uppermost band of the system.

In grouping the various habitats of these forms of British trilobites, I would direct the attention of the reader to the descriptions of the lower paleozoic fossils in the Cambridge Woodwardian Museum, by Professor M'Coy, in order that he may see how many species, even in that one rich collection, are common to what have been so long and so generally called the Lower and Upper Silurian rocks.

He will see that out of fifty-one species of trilobites there enumerated —being double the list first published in my original work, nearly all the new forms have been found in localities of Montgomery, Radnor, Brecon, Carmarthen, and Pembroke, which were laid down by me as Lower Silurian on the map,—a pretty strong indication that the region first described as Silurian still affords the best fossil types.

It is here important to remark, that the impressions of footmarks in the Potsdam sandstone or lowest Silurian rock of North America, which were at first supposed to have been made by tortoises, have, in consequence of the discovery of better specimens, been subsequently referred by Professor Owen to crustaceans*; and tracks of a similar kind, but far smaller, have been found in our own country (*ante*, p. 168). Hence this last class of animals may still be considered the highest type of life in the earliest primeval strata known. It is, indeed, a remarkable fact, that the most sedulous research in many parts of the world has failed to discover the trace of any vertebrated animal in the lower division of the Silurian system. All the marine animals—amounting to many hundred, perhaps even to a thousand, species—already known belong to the invertebrated classes; no true fish having yet been observed†. This observation applies also to the Upper Silurian rocks of Britain, with the exception of their highest band, as formerly explained in the 'Silurian System.'

* See Journ. Geol. Soc. vol. vii. p. 247, and vol. viii. p. 223. The zeal of that acute and laborious geologist, Sir William Logan, in procuring specimens and casts of a very great number of these large and curious impressions, cannot be too much commended. In default of these labours, most erroneous ideas would have been propagated respecting the Lower Silurian fauna.

† Portions of very minute fossils from the Lower Silurian of Russia have, indeed, been described by Pander as belonging to fishes. The specimens sent to me have satisfied the naturalists to whom they were submitted (Dr. Carpenter and Prof. Quekett), that these microscopic bodies do not exhibit a fish-like structure. Being unwilling, however, to set aside, without strong reasons, the opinion of so good an observer as M. Pander, whose last work, a monument of his skill and patient research, came to hand only whilst these pages are printing, the subject will be reconsidered in the sequel.

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Having thus referred to the figures first published in my original work, and now reproduced at the end of this volume, as well as to other types of Lower Silurian age which have been subsequently discovered, we now pass on to consider the assemblage of fossil animals specially characteristic of the Llandovery rocks—the formation which connects the Lower and Upper Silurian divisions.

Fossils of the Llandovery Rocks.—The principal organic remains belonging to this zone, which I previously regarded as a portion of the Lower Silurian rocks, are now eliminated from the catalogues through which they were diffused in the 'Silurian System' and in the first edition of this work, and are here brought together. (See Plates 8–11.)

This important and varied group, which is also found to intervene between the much greater masses of the Lower and Upper Silurian rocks in Russia, Scandinavia, and America, is nowhere more largely developed than in the British Isles. Though linked on to the Lower Silurian by several typical forms, the fauna of these rocks has, on the whole, a peculiar facies; and many of the species in the superior division of the series are Upper Silurian. The great number of trilobites we have been considering in the earlier part of this chapter have disappeared, and a few rare species of those ancient crustaceans, including one or two that are specially distinctive of this intermediate series, are mingled with others which become plentiful in the Upper Silurian rocks. The prevailing corals, brachiopods, and univalves differ but little from these of the inferior strata; there being several typical shells which have continued to live on. On the other hand, certain forms which have not been found in the Llandeilo or Caradoc formations, give a marked impress to this group. Some of these discrepancies may, no doubt, be due to the gravelly and sandy nature of the strata, compared with the more argillaceous materials of the Lower Silurian rocks; but this explanation will not suffice when the arenaceous members of both groups are put in comparison.

Though Graptolites are rare, the G. priodon is present, a species which ranges from the true Lower Silurian up to the Ludlow rocks. The corals are by no means few in number, and many of them—such as the chain-coral, the various species of Favosites and Heliolites, Syringopora, &c.—are the same as those known in the Lower and Upper Silurian. The Favosites Gothlandicus and Heliolites interstinctus are common everywhere, and these species seem to have been indifferent (as very common species usually are) to the nature of the sea-bottom on which they lived. Some new species are added, both of the millepore and cup-coral groups, which will be noticed in their proper places.

The cup-corals chiefly belong to the genus Petraia, which is eminently characteristic of the Llandovery rocks, but comparatively rare either

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above or below them. The most common species is the Petraia subduplicata, Foss. 28. f. 3, which, with its elegant variety, crenulata, occurs in nearly every locality, both in the upper and lower portions of the deposit, in Wales, Scotland, and western Ireland. Petraia elongata, Phill., a larger species, is more common in the upper than in the lower beds, as at May Hill, Presteign, &c.; while the P. bina, Lonsdale, Foss. 52. f. 7, is apparently confined to the upper division, and ranges into the Wenlock rocks. P. æquisulcata of M'Coy, another large species, occurs near Girvan in Scotland, and, with P. subduplicata, is sometimes found in true Lower Silurian rocks. A square species of Petraia, P. quadrata, M'Coy, is found in the Galway strata; it belongs to the genus Goniophyllum, Milne-Edw., and is the same as the Gothland Wenlock species, Gon. quadratum (according to the French Professor). There are also other species, as well as some cup-corals of a larger size, which may be species of Cyathophyllum or Omphyma, and these are chiefly in the superior strata of the formation.

The class of Bryozoa or Polyzoa, which is not absent from the Lower Silurian rocks, as before mentioned, is represented here by several species. Though not yet clearly defined, they have been chiefly referred to branched forms of the genus Ptilodictya. P. dichotoma, Portlock, Foss. 28. f. 5, a Lower Silurian species, is the most frequent; but the Wenlock forms, P. lanceolata and P. scalpellum, Foss. 49. f. 6, & 50, also occur, with several incrusting species. The most remarkable of these, if, indeed, it be allowed to remain in this group of fossils, is the Nidulites favus, Foss. 27. f. 3. This fossil is characteristic of the Lower Llandovery series both in S. Wales (Haverfordwest) and in the S. of Scotland (Girvan), in each of which localities it is associated with the same fossils. It was for some time believed to be the nidus of a gasteropod, similar to that made by the modern Natica*, the cup-like form of which it imitates. This explanation fails, however, when the fossil is more closely examined; since the cells are equal and regular on both sides of a central lamina, and are set back to back like the cells of a honeycomb—whence the name. At the bottom of the cells a minute pit or depression is frequently visible, and this becomes a tubercle on the cast (in which state the fossils are always found). No trace of any upper plate or cover to the cells (which would exist in all the analogous types of Bryozoa) has been detected. The cells would seem to have been quite open at the top, and, as their size is greatly larger than any living species of that group, the exact affinity of the fossil has yet to be determined.

Fragments and stems of Encrinites are not uncommon, but no perfect specimens have yet been obtained; although throughout the conglomerates and sandstones of this age in S. Wales, Encrinite stems are the chief, and often the only fossils. These stems are usually hollow, a

* See Quart. Geol. Journ. vol. vii. p. 174.

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character common to all the Lower Silurian species; while those of the Upper Silurian are chiefly compact, with a small perforation only. The Llandovery rocks contain, however, both these kinds. A large species of Encrinite, with tuberculate joints alternating with very narrow, plain joints, is found everywhere in the Upper Llandovery strata, and is figured from Presteign, where it abounds (Pl. 10. f. 1).

Cystideæ are very rare—a few detached plates occurring here and there in S. Wales; the curious genus Glyptocystites (p. 207) is, however, found at the base of the series near Llandovery. The same species, G. Rugeri, MS., also occurs in the immediately underlying Caradoc formation. When this family of Echinoderms appears in Upper Silurian strata, the species, and indeed most of the genera, are quite distinct from those of the Lower Silurian rocks.

The Brachiopods are, as throughout the Silurian system, the most abundant fossils; and, as might be expected, the species which range from the lower to the upper division are the most common. The genera Orthis, Leptæna, and Strophomena are still prevalent, and many of these are the same species which have been quoted as Lower Silurian types. Discina is seldom met with. Rhynchonella and Atrypa, which are rare in Lower Silurian rocks, become plentiful, and Spirifer appears for the first time.

The Pentameri are, however, the characteristic fossils which impart to this zone its peculiar and distinct facies. No less than five species, whether smooth or only slightly ribbed, occur, and of these, the P. oblongus is the best known and the most widely spread. This typical shell is easily distinguished from the other species, P. lens and P. liratus, by the great length of the mesial septum, which in these latter is quite a short appendage to the V-shaped chamber*. The two longitudinal plates, also, which divide the upper valve, are peculiar to this species; whilst in P. lens they are very short, and in P. liratus are reduced to a pair of processes which pass inwards, but do not show upon the surface of the cast. P. globosus is a rare species, easily recognized by its globular shape; and P. undatus is small and broad, with a wide central fold, and very short dividing plates (see Plate 8).

The distribution of these species is as follows:—In the Lower Llandovery rocks of S. Wales, the P. undatus and P. lens are everywhere found, the P. globosus and P. oblongus being rare. In the upper series,

* The P. undatus, a most abundant species, is considered by M'Coy to be identical with the P. linguifer of the Woolhope and Wenlock limestones. The great point, however, on which I relied in formerly classing these rocks as Lower Silurian, was the invariable absence of their type shell P. oblongus, and its usual associates, from all the Upper Silurian rocks. For a description of the structure of Pentamerus, consult Mr. Davidson's Monograph, Palæontographical Society, vol. i. p. 97; and for excellent descriptions of the species, see Prof. M'Coy in the Synopsis of the Woodwardian Museum. The P. microcamerus of this author appears not to be distinct from P. lens.

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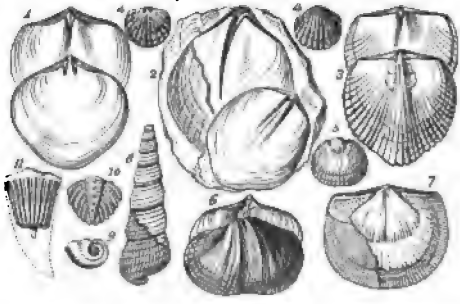
whether in S. Wales, Shropshire, or in the S. of Scotland (as at Saugh Hill near Girvan), the P. oblongus is the prevailing fossil, occurring often in great banks to the exclusion of all other fossils, but generally accompanied by the species just named. At May Hill and the Malverns, the

FOSSILS (47). TYPICAL LLANDOVERY FOSSILS.

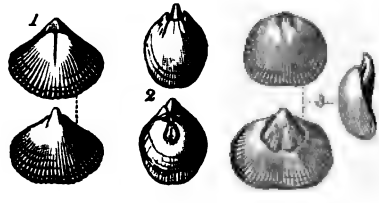


1. Pentamerus lens. 2. P. oblongus. 3. P. liratus, Sow. 4. Atrypa hemisphærica. 5. A. reticularis. 6. Pentamerus undatus. 7. Strophomena compressa. 8. Holopella cancellata. 9. Bellerophon trilobatus. 10. Encrinurus punctatus. 11. Petraia subduplicata, M'Coy.

P. lens is by far the more common species; P. liratus accompanies both these in the higher beds, and is the only one of the five species which ranges into the base of the Wenlock formation.

Of Terebratuloid shells, two or three are typical of the formation. The characteristic species of the Lower Llandovery rocks is the smooth shell, the Rhynchonella (Hemithyris) angustifrons, M'Coy, Foss. 48. f. 2.

FOSSILS (48). LLANDOVERY BRACHIOPODS.



1. Rhynchonella serrata, M'Coy. 2. R. angustifrons, M'Coy. 3. Orthis reversa, Salter. All occur in the S. of Scotland and the W. of Ireland.

It was first described from the sandstones of Mulloch, Ayrshire, and has since been detected near Builth, and in the lower beds at Llandovery. It is indeed doubtful if it can be referred to Rhynchonella; being probably of the same genus with the so-called Atrypa crassa, Pl. 9. f. 7, one of the commonest species in the same beds, and apparently confined to them. R. furcata, Pl. 9. f. 12, one of the same group, is an Upper Llandovery species. R. decemplicata, f. 15, is a characteristic shell of the Upper Llandovery rocks, and abounds through the Malvern and May Hill districts, and round the flanks of the Longmynd. It is never found in the Lower Llandovery beds, but occurs in the Denbighshire sandstones,

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associated with Upper Silurian fossils only. R. nucula, Pl. 22. f. 1, occurs with it at Tortworth and May Hill. Another species, which cannot be distinguished from the R. obtusiplicata of Hall, is found in the conglomerates on the west flank of the Worcester Beacon, Malvern. The R. serrata, Foss. 48. f. 1, a beautiful shell, with R. sexcostata, M'Coy, are found in Galway, the former also in Ayrshire. R. cuneata and R. borealis are met with in the S. of Scotland, with R. Wilsoni. The last fossil is thenceforward persistent throughout all the deposits to the Upper Ludlow inclusive. R. Grayii, Foss. 57. f. 3, and R. didyma, both characteristic Wenlock forms, are found in the upper beds, near Llandovery.

The genus Atrypa is very abundant. A. marginalis, Pl. 9. f. 2, is one of the common fossils of the formation. A. reticularis, Linn., Pl. 9. f. 1, and Foss. 47. f. 5, appears to have commenced with the Llandovery period and ranges upwards throughout all the overlying Silurians. On the other hand, the A. hemisphærica, Pl. 9. f. 3, is confined to the Upper Llandovery beds. This species swarms at Tortworth, Presteign, and Abberley, but is rare in Wales. Spirifer elevatus and S. trapezoidalis are found at Tortworth and May Hill (see Plates 9 & 21).

The well-known Lower Silurian Orthides, O. calligramma (not flabellulum) and O. elegantula, Pl. 9. f. 19 & 21, are somewhat frequent in the Llandovery rocks, and are also occasionally accompanied by O. Actoniæ and O. insularis, Pander. Other species peculiar to these rocks are: O. reversa, Salter*, Foss. 48. f. 3, and O. lata, Sil. Syst., Pl. 9. f. 23, whilst O. biloba and O. elegantula, which are Upper Silurian species, are also known in both divisions of this formation.

Of the genus Strophomena, the widely spread S. depressa, which ranges from the Llandeilo to the Wenlock rocks, and S. antiquata, are common in the lower division; the S. bipartita, of Caradoc age, and S. euglypha, of the Wenlock deposits, are more rare. In the upper beds, S. compressa, Pl. 9. f. 16, with S. pecten, Foss. 58. f. 3, and a new species, S. arenacea, MS.†, are frequent types.

The Leptæna transversalis and L. sericea, Pl. 9. f. 18, both well-known Lower Silurian fossils, with a small new species, L. scissa, MS., are found in both of the Llandovery divisions, the first-named being the most common fossil.

Of Lingulæ there are a few species: the L. crumena, Phillips, Foss. 12. f. 5, p. 74, and L. parallela, Phill., are common at Malvern, and there is a species yet unnamed, in the Lower Llandovery rocks. Discina (Orbicula, Sil. Syst.) is very rare; but the small Crania implicata, Pl. 20. f. 4, is found occasionally in the higher beds.

The above-mentioned brachiopod shells are by no means equally distributed throughout the various localities where the Llandovery strata

* Griffith's Synopsis Silurian Fossils of Ireland, Appendix, pl. 5. f. 2.

† These new species will be soon described in the Memoirs of the Geol. Survey.

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crop out. In the Abberley, Malvern, and Tortworth districts, the Atrypa hemisphærica is the common fossil, and Pentameri are rare. At May Hill, and round the flanks of the Longmynd, on the other hand, the various species of Pentamerus prevail, and are accompanied by Orthis calligramma and O. reversa, Strophomena compressa, Spirifer plicatellus, and S. elevatus, and at May Hill by a rare Chonetes lata. The Malvern district is rich in a variety of fossils. Besides the Pentameri, Rhynchonella decemplicata, R. furcata, and several other species of the genus, not yet named, we there meet with many fine Lingulæ, which have been above noticed. In the Abberley Hills, Atrypa hemisphærica is the common fossil.

The small outlier at Presteign (p. 118) contains few species, but these attain a large size; the Pentamerus oblongus and Atrypa hemisphærica being profusely distributed in it. Along the S. Welsh frontier the upper and lower divisions are marked by their peculiar Pentameri, as already noted, p. 97.

In the cliffs of Marloes Bay, Pembrokeshire, where the Llandovery rocks assume a peculiar mineral structure (see p. 159), the ordinary Brachiopods still prevail. Thus, the Pentamerus liratus lies at the base of the Wenlock series, with a thin layer of P. oblongus underneath. These are in that locality the only representatives of the genus. Rhynchonella decemplicata, and a new species with two raised ribs in front, Strophomena compressa, and Atrypa hemisphærica, are, however, common. In Galway the Orthis calligramma forms entire beds, and the only Pentamerus yet found there is the P. oblongus. Atrypa hemisphærica is also there both numerous and of great size; and Orthis reversa, with the Rhynchonella serrata, are common. These species also abound in Ayrshire, where the R. serrata, and small forms of the Atrypa hemisphærica lie in the upper beds, and a large variety of the latter species, with Rhynchonella angustifrons and Orthis reversa in the lower. The distribution in Ayrshire is, therefore, like that in S. Wales; and the other groups of fossils, as well as the Brachiopoda, follow the same rule.

Lamellibranchiate shells are not common, but certain species are characteristic of the formation. A long variety of the Pterinea (Avicula) retroflexa, Pl. 23. f. 17 (P. demissa, Conrad), is plentiful at Malvern, and also in the Connemara tract of Galway, where two or three other Ludlow rock forms occur, such as P. sublævis and P. bullata, M'Coy, with P. lineatula, Pl. 23. f. 16. A small species, perhaps inaccurately referred to the genus, P. planulata, Foss. 59. f. 6, is not uncommon in the upper beds of the formation; it is a Wenlock species. Cucullella ovata and antiqua are found in Galway.

Two or three rather large species of Nucula occur near Malvern, such as the N. lingualis, Phillips, N. rhomboidea, of the same author, and its variety N. deltoidea. There, too, the remarkable thick species, Cteno-

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donta* (Nucula) Eastnori and C. subæqualis, Pl. 10. f. 7–9, abound. Nucula ovalis, Pl. 23. f. 10, and N. subcylindrica, M'Coy, are Galway species. Lyrodesma (Actinodonta) cuneata, Phillips, is characteristic of the Upper Llandovery beds in Pembrokeshire.

A few Mytiloid shells are to be noticed. These are: M. mytilimeris, Foss. 60. f. 6, at Llandovery and May Hill; two or three species of Modiola at Tortworth; and the small Anodontopsis (Lucina) bulla, f. 5, a species which has lived on to the close of the Ludlow rocks, and was first described by M'Coy from Galway. Orthonotus semisulcatus, Sow., is recorded by that author from the Ayrshire sandstone, and O. rotundatus, Pl. 23. f. 5, from Galway, where, too, a solitary species of Pleurorhynchus, P. pristis, Salter, has also been found.

If the Lamellibranchiate shells do not present any marked characters, it is otherwise with the Gasteropods, which are numerous and peculiar. Both turbinate and elongate forms abound; such as angular species of Pleurotomaria and Murchisonia, the depressed form Raphistoma (so common in the Lower Silurian), Euomphalus, Trochus?, Holopea and Holopella. Macrocheilus, Acroculia, Patella, and even Chiton are also found here. The last is particularly interesting, carrying back, as it does, a marked and common living genus to this middle Silurian time†. It is of so elongate a form, that the term Helminthochiton was applied to it by Mr. Salter, who described it so far back as 1846 in Mr. Griffith's Synopsis of the Silurian Fossils of Ireland. Acroculia Haliotis is rare in the upper beds, in which only Euomphalus funatus and E. sculptus, so abundant at Tortworth, are found. There are several undescribed species of Turbo; though some shells referred to this genus evidently do not belong to it, but are thin shells with strong striæ of growth, and raised ridges round the whorls. Such are T. trochleatus of M'Coy and T. tricinctus, M'C., from Galway; and such, also, may be the thin American shells called Cyclonema by Hall, and of which C. ventricosa of that author is found at Tortworth. The little Turbo tritorquatus, M'Coy, from Llandovery, and also from Galway, may belong to this group; there is but slight evidence, however, that any of the above-named species belong to the genus to which they have been assigned.

The genus Trochus, so-called, numbers two, if not three species. The T. Moorei, M'Coy, is probably a Pleurotomaria; but the T. multitorquatus of that author, which (or an allied species) appears to occur both in Ayrshire and Pembrokeshire, can scarcely be referred at present to any other genus. It is a most remarkable shell, with at least seven flat whorls.

* Isoarca has incurved beaks and a wide ligamental area; otherwise these Nuculæ with external ligaments would belong to it. See p. 213. Also J. Hall, Descriptions of New Fossils, Report of the Regents of the University for 1856, Albany, 1857, pp. 141 &c.

† Prof. de Koninck, of Liége, has lately detected two other species in the Dudley shale.

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Pleurotomariæ and Murchisoniæ are common fossils. P. (Turbo) Pryceæ and P. angulata, Pl. 10. f. 11, 12, are found throughout the Lower Llandovery of Wales. The inhabitants of these shells seem to have delighted to live upon the sandy and pebbly shoals which, now formed into conglomerate, are so frequent in the hills on the right bank of the Towy. Murchisonia simplex, M'Coy, is found in similar situations, but in a less coarse matrix; it is also a true Lower Silurian species. M. cancellatula, M'Coy, is an Ayrshire fossil, and M. pulchra, M'Coy, a Galway species. A large angular shell, to which Mr. Salter applies the MS. name P. bicoronata, is very common at Haverfordwest and in other parts of Wales. Raphistoma lenticularis, Pl. 10. f. 10, is everywhere met with in the Upper Llandovery. Two or three species of Holopella (Turritella of my old work) are found in the same zone at Tortworth, and appear to be also the common species of the uppermost Ludlow rock—T. obsoleta, T. gregaria, &c. These have been found in Galway too by M'Coy, as well as a new species, H. plana, M'Coy. H. tenuicincta of the same author is a Lower Llandovery form, while H. cancellata, our largest British species, often three inches long, is common to the Lower and Upper Llandovery, and abounds in still higher beds at the Bogmine near Shelve in Shropshire. An angular-whorled Loxonema is found at Marloes Bay; and Macrocheilus fusiformis, the largest of the Gasteropods of the Llandovery rocks, is a rare fossil from Presteign.

The Pteropods contribute a few species, of which Conularia Sowerbyi, Pl. 25. f. 10, Cyrtolites Scoticus, M'Coy, and a fine species of Pterotheca are the chief. The last, which much resembles P. transversa of the Lower Silurian, occurs in the Upper Llandovery rock of Tortworth.

Of Bellerophon, no less than eight species have been already observed, and there are probably many more. The great B. dilatatus, Pl. 25. f. 6, is found both in Lower and Upper Silurian, as well as in this band. B. bilobatus, Pl. 7. f. 9, so common in the Caradoc sandstone, and so characteristic of the Lower Silurian of France, Spain, and Bohemia, ranges up into the Lower Llandovery in Ayrshire, where B. subdecussatus, M'Coy, and at least two other unnamed species occur. Lastly, the B. trilobatus, one of the uppermost Ludlow or Tilestone species, Pl. 34. f. 9, is found both at Tortworth and in Galway.

A few Cephalopoda only have yet been described from these deposits, though they are not rare. Orthoceratites, of both smooth and annulated forms, are indeed often met with. The Orthoceras conicum, Sow., of the Sil. Syst. pl. 21. f. 21, is perhaps the most frequent in the upper beds. O. Barrandei, Salter, of Ayrshire, is one of the shortest forms known, and is figured in the Quart. Geol. Journal, vol. vii. pl. 9. f. 19. O. tenuistriatum of Münster, a species with fine longitudinal striæ, occurs at Haverfordwest and in Ayrshire; and the O. bullatum, Pl. 29. f. 1, and O. angulatum, Pl. 28. f. 4, are quoted by M'Coy from Galway. Prof.

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M'Coy mentions five or six smooth species from the Galway beds, including the O. tenuicinctum of Portlock. As these species range from Lower to Upper Silurian, it is most important to note this fact, in treating of a band which unites those two great divisions.

The most remarkable of all these cephalopods is the Tretoceras bisiphonatum, a singular Orthoceras with a double siphuncle, or rather (as shown by Mr. Salter) with a deep lateral tube piercing the septa, as well as a siphuncle. This remarkable fossil should be sought for by collectors. It is figured in Pl. 11. f. 5, from the Upper Llandovery rocks of Gorllwyn, near Llandovery, S. Wales. Lituites cornu-arietis, a Caradoc species, occurs in the lower division of these rocks at Llandovery; Cyrtoceras (Orthoc., Sil. Syst.) approximatum, Pl. 11. f. 4, at Eastnor Park; and a fine large species, yet unnamed, of the latter genus was obtained from the precipitous strata of Castell Craig Gwyddon, near Llandovery. Lastly, the Phragmoceras (?) compressum, Pl. 31. f. 4, a Wenlock fossil, has occurred, with many Lower Llandovery species, in the hard sandstones of Thrave, near Girvan, Ayrshire.

Annelida are plentiful; both the Tentaculites Anglicus, Pl. 1. f. 3, and Cornulites serpularius, Pl. 16. f. 3–10, being the common fossils in Tortworth and other districts. They are less frequent in the lower division. Tentaculites ornatus, Pl. 16. f. 11, is rare, but is found in Ayrshire.

Of Trilobites few species are characteristic. If we except the Phacops Weaveri, Salter*, a large species of Illænus like I. Bowmanni, which is frequent in S. Wales, and also occurs in Shropshire and Scotland, there are no forms known to be peculiar to this intermediate formation. Of these species, it is remarkable that the P. Weaveri is found in beds of corresponding age at Point Gaspè, in the distant region of Canada. The species of Illænus above quoted differs considerably from I. Bowmanni of the inferior rocks, which, nevertheless, is found here with it. The last-named fossil, with Lichas laxatus, M'Coy, and probably the Asaphus latifrons, Portlock, or its closely allied form, are three Lower Silurian species of Trilobites which range into these Llandovery rocks. The other Trilobites are well-known Upper Silurian types, viz. Phacops Stokesii and P. caudatus (the former common, the latter rare), Acidaspis Brightii, and Cheirurus bimucronatus, with the small Cyphaspis megalops and Proetus latifrons, M'Coy. The most common of all is the Encrinurus punctatus; whilst the Calymene Blumenbachii, which ranges from the Snowdon or Caradoc rocks to the Upper Ludlow, is not unfrequent. Lastly, it is also to be observed, that a fragment of the Pterygotus was detected by the late H. E. Strickland in the Malvern district.

No traces of fish-remains have been discovered in British deposits of this age, nor in the overlying Wenlock rocks.

* Mem. Geol. Surv., Decade 1. pl. 1. f. 16.

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The reader who has perused the preceding details respecting the distribution of organic remains, as well as those former chapters which treat of the ascending series of Silurian deposits constituting the system, will have perceived, that the sharp distinction which was at first supposed to exist between the Lower and Upper Silurian rocks no longer holds good. When my classification was proposed in the year 1835, scarcely one of those species which were considered typical of the inferior division had been observed to pass upwards into the superior group, and yet the community of genera convinced me, that the whole should be united in one natural system. Seeing that the type shell of the Llandovery and May Hill sandstones, the Pentamerus oblongus, was never detected in the overlying Wenlock shale, and was associated with certain species which belonged to the lower part of the series,—and influenced also, to some extent, by mineral characters, I classed the former as the summit of my Lower Silurian rocks.

With the enlargement, however, of the field of examination, not only by the survey of all Wales, but by researches in Ireland and Scotland, and by the more exact comparison of the fossils, it has become evident, that, whilst a great number of species pervade nearly the whole system, the zone so laden with Pentameri, to which the term Llandovery Rocks has been applied, is truly of intermediate character. In short, its inferior member contains many Lower Silurian types, and its superior strata are unquestionably more connected with the Upper Silurian group (of which, throughout many tracts, they form the natural physical base), and are locally transgressive to the inferior rocks. Hence, in the legend attached to the Map, the Lower Llandovery is grouped with the inferior division; the Upper Llandovery, though still characterized by the same Pentameri as the lower mass, being linked on to the superior strata.

It is, indeed, important to give a prominence to this connecting zone, by treating separately of its characteristic fossils; for, as will hereafter appear, there are foreign countries (Scandinavia and Russia) in which there is no discordance of strata, and where the stratigraphical and lithological passage from Lower to Upper Silurian is in perfect harmony with the zoological transition above described.

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CHAPTER X.

FOSSILS OF THE UPPER SILURIAN ROCKS.

THE reader has already been told that many species of fossils, once supposed to be peculiar respectively to the Lower or Upper Silurian rocks, are now ascertained to be common to both, and necessarily to the intermediate and connecting group.

This datum is the result of the researches of various geologists and paleontologists, whether in the region first explored, or in tracts of far greater extent which have recently been paralleled with it. Similar results have, in truth, invariably followed from a full and broad development of the natural geological groups of the secondary and tertiary strata, which were described and classified before the older rocks of which we now treat had been brought into order, or even into notice. Thus, for example, when the different members of the oolitic formations reposing on the lias were studied in one tract only, as on the eastern coast of Yorkshire, they were seen to be there composed of a series of zones, each of which is sharply separated from the contiguous deposits by fossils confined to it. In tracing, however, the same strata to remote distances, certain remains, which were once viewed as typical of one member only, were found to be common to several subformations; thus combining the whole in one natural system—the oolitic or jurassic.

This is just what has happened in the lower paleozoic rocks, now that the inferior and superior masses, and the chief formations and subdivisions of Siluria, have been ascertained by my cotemporaries to occupy nearly all North and South Wales, large tracts of Cumberland, Westmoreland, and Lancashire, great regions in Scotland and Ireland, and various parts of Europe and America.

In short, the two chief divisions, which, from a general similarity, were originally grouped together, have been demonstrated to constitute a natural system, through a community of organic remains. For, even if the contents of the intermediate middle zone of Llan-

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dovery rocks be abstracted from the estimate, still there are many species—from fifty to sixty—which range from the Llandeilo and Caradoc deposits into the Wenlock and Ludlow rocks.

The vertical range of all these fossils through the chief Silurian deposits will, indeed, be given at the end of the volume, in a Table which has been prepared by Mr. Salter aided by Professor Morris.

To some of the most striking of these remains which pervade the whole system, allusion has already been made (Chap. IX.), and notice will now be taken of other forms, of like duration in time, which are more abundant in the upper division. The attention, however, of the reader will be directed chiefly to the types which are peculiarly, and, as far as our present knowledge goes, exclusively, Upper Silurian. (See Plates 13–35.)

The Graptolites, which, as before stated, are so very abundant in the shaly and schistose portions of the Lower Silurian of Wales and Scotland, become much more scarce as to species in the Upper Silurian; and, though there are many tracts where the Wenlock shale and Lower Ludlow rocks are crowded with them, it is only one* species—the Graptolites priodon—that is abundant in these upper divisions of the system. When argillaceous sediments abound in these rocks, the Graptolite is rarely absent; but with the cessation of such peculiar conditions, this zoophyte, which must have grown on the fine mud at the bottom of the sea, disappears.

One of these Graptolites, which occurs in the old rocks of Snowdon, ranges through the series even to the Upper Ludlow rocks, and hence was named G. Ludensis before it was identified with G. priodon. In the Wenlock shale, especially towards the base of that deposit, that fossil is sometimes accompanied by a very beautiful and peculiar species —the Retiolites Geinitzianus of Barrande. The latter occupies the same position (at the base of the Upper Silurian series) in Bohemia, whence it was first described. It is a double Graptolite, like the genus Diplograpsus (see Pl. 1. f. 2), from which, however, it differs essentially in having no central axis, and in having the surface composed of a reticular tissue instead of a continuous horny coat. An excellent figure of it is given in the memoir of M. Barrande on the 'Graptolites of Bohemia.' Above the Ludlow rocks, and throughout the whole series of overlying paleozoic strata, no true Graptolite, as before observed, has ever been found; and I repeat, therefore, that this animal is a marked Silurian type.

* Another species has been detected (but only in one locality, where it is plentiful) in strata believed to be of Wenlock age. It is Grapt. Flemingii, Salter, found in Kirkcudbright Bay, where it was first collected by the Earl of Selkirk. See Quart. Journ. Geol. Soc. vol. viii. pl. 21. f. 5, 6.

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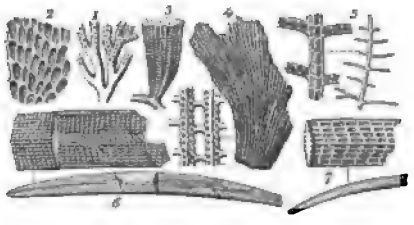
It should further be observed, that in Britain neither the double or foliaceous Graptolite (Diplograpsus), nor the twin Graptolite (Didymograpsus), are ever met with above the horizon of the Caradoc formation. They are, therefore, excellent indices of the lower division. But in Bohemia, as we learn from the work just cited, the foliaceous types are mixed together with the single-sided forms (Graptolites) in the lower part of the upper division.

FOSSILS (49). UPPER SILURIAN BRYOZOA.

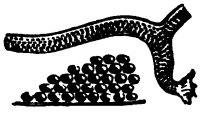


1. Polypora? crassa (Hornera, Sil. Syst.). 2. Fenestella assimilis (Gorgonia, Lonsd.), a common Wenlock species. 3. F. Lonsdalii, D'Orb. (F. prisca, Sil. Syst.). 4. F. Milleri, Lonsd. 5. Glauconome disticha, Goldf. 6. Ptilodictya lanceolata, Goldf., a reduced figure of a full-grown specimen; a part is figured above it, natural size. 7. is the young state; the cells are longer in proportion.

The other Bryozoa, besides Graptolites (if we may now safely rank these last with the class, see pp. 64 & 203), are numerous, but not of as many species in the upper, as in the inferior division. The Ptilodictya has been already quoted in the Lower Silurian. A large species, P. lanceolata, Foss. 49. f. 6, is abundant in Wenlock strata (f. 7 is the young state of it); and P. scalpellum (Eschara, Sil. Syst.), Foss. 50, accompanies it: the former occurs also in the Ludlow rocks. Glauconome disticha, Foss. 49. f. 5; Fenestella Milleri, f. 4; and F. subantiqua,

FOSSILS (50). WENLOCK BRYOZOON.

Ptilodictya scalpellum, Lonsdale (Eschara, Sil. Syst.), natural size. Also a portion magnified. It is a



common species in the Wenlock limestone, and grows larger than represented in the figure.

Foss. 27. f. 1, are common fossils at Dudley. Another common species, F. assimilis (Gorgonia, Sil. Syst.), Foss. 49. f. 2, is also figured, as well as the beautiful little cup-shaped Fenestella of the Wenlock limestone, F. Lonsdalii, D'Orb., f. 3. Polypora (Hornera) crassa, f. 1, is not so often met with.

The true corals (Zoantharia of naturalists) are far more characteristic of the upper than of the lower members of the Silurian rocks, and they are more abundant in them, both as to species and individuals; the

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nodular limestone bands of the Wenlock and Aymestry rocks being frequently made up of corals, or of concretions having coralline bodies as their nucleus or on their surfaces.

When Mr. Lonsdale undertook, at my request, his admirable description of the corals of the Silurian region, and carefully superintended the drawing of their forms, sixty-two species only were recognizable in our collections; and these included the Bryozoa above mentioned, now known to be closely allied to mollusks. But the number of corals has been greatly increased of late years, chiefly, as regards Britain, by the researches of Prof. Milne-Edwards and Prof. M'Coy. Several new genera have been formed, which, as they are founded on peculiarities of structure, growth, and reproduction, are likely to prove of permanent value to the zoologist and geologist.

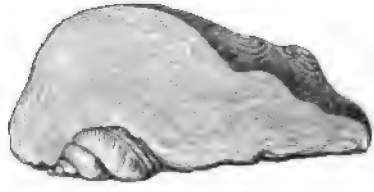
One of the most important of these discoveries, resulting from the labours of Prof. Milne-Edwards, and his coadjutor M. Jules Haime*, appears to be, that the bulk, if not all the corals of the Silurian system, and indeed of the whole paleozoic era, belong to divisions of the coral tribe unknown in modern seas: with rare exceptions, these groups became extinct at the close of the paleozoic epoch. If this be established, and the large cup- and star-corals (Zoantharia rugosa) and the massive millepores (Z. tabulata) be, as a whole, distinct in structure from th star-corals and madrepores of the tertiary rocks and of the existing coral reefs, we gain a new fact in the history of animal life upon the globe, which is in harmony with results obtained by the study of the crustacea, mollusca, and fish of the older epochs.

A number of corals which pass from the Lower to the Upper Silurian rocks have already been enumerated, Chap. 5; and as these are generally the most abundant species in the younger division, a brief list of them is here given.

The chain-coral, Halysites catenularius, Foss. 19. f. 6, is one of the most frequent; Favosites Gothlandicus, Foss. 17. f. 2, 3; F. alveolaris (F. aspera of d'Orbigny), f. 4; Stenopora (Favosites) fibrosa, f. 7, 8; Heliolites interstinctus (Porites pyriformis, Sil. Syst.), Foss. 18. f. 4, 5, and the var. H. megastoma, M'Coy (?), f. 3, H. tubulatus, f. 1, and H. petalliformis, f. 2. Besides these, there is the doubtful fossil, Stromatopora striatella (concentrica, Sil. Syst.), Foss. 51, usually arranged with the corals, and much resembling them. Its true position is uncertain, and it may even belong to the tribe of Sponges.

FOSSILS (51).

A section of Stromatopora striatella, d'Orb.



A very common Wenlock limestone fossil.

* Archives du Mus. d'Hist. Nat. vol. v.

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In addition to those just quoted, several of the conspicuous corals of the Upper Silurian strata have already been enumerated, p. 133. Of the latter it may be truly said, that they swarm in the Wenlock limestone, are found, in diminished numbers, in the Aymestry rock, and are much less plentiful in the muddy sediments of the Wenlock shale and Lower Ludlow rock.

Of the prominent species, Favosites alveolaris and F. Gothlandicus are, perhaps, the most generally diffused, and occur in masses varying from the size of a hazel-nut to two and three feet in diameter. The former may be easily distinguished (p. 132, Foss. 17. f. 4) on breaking the mass, by the angles of the tubes being toothed, while those of the other (f. 2, 3) are smooth-edged regular prisms, on which the double row of pores is very conspicuous. F. cristatus, f. 1 (polymorpha of the Sil. Syst.), is almost as frequently met with, and forms whole strata on the coast of the Dingle promontory in Ireland. All the three species range, indeed, up to the Devonian period*, and are widely distributed over the Northern hemisphere. The various forms of the Stenopora (Favosites) fibrosa are not less common; but this latter fossil does not appear to be so abundant in the Upper as in the Lower Silurian, nor to assume so many variations in form. It is globular, lobed, or branched; and on the slabs of limestone at Dudley there very commonly occurs a narrow branched variety, with numerous small pores intermixed with larger ones. This form is very curious, and is figured in my larger work (Sil. Syst. pl. 15 bis, f. 9)† as a variety of Favosites spongites, Goldf. Professor Milne-Edwards believes it to be of a different genus, and has named it Chætetes Fletcheri, in honour of a gentleman who has long been a judicious collector of the Dudley fossils.

The species called Favosites oculatus (see Chap. 6. Foss. 17. f. 6) is very abundant in the Wenlock limestone. But it may be doubted if it belongs to the genus: it is named Alveolites repens in the work of Milne-Edwards and Haime.

Next in importance to the Favosites are the large species of the genus Heliolites. Of these, the most common, H. interstinctus, Foss. 18. f. 3, 4, 5, occurs either in globular and pear-shaped masses, or of a flat discoid form, or as a thin incrusting expansion over other corals and shells.

Alveolites Labechii, M.-Edw., a coral two or three inches broad, which looks like a small-celled Favosites, and was named F. spongites in my old work, is very characteristic. It is known by the oblique or compressed mouths of the cells, Foss. 17. f. 5.

* It is right to state that M. Milne-Edwards distinguishes all the Devonian from the Silurian corals.

† For a further acquaintance with the corals of the Wenlock and Ludlow rocks, I must refer the reader to the 'Silurian System,' and the faithful and able descriptions by Mr. Lonsdale. The plates of corals in that work, being lithographs, could not be reproduced here; but the woodcuts will, in some measure, help to supply the deficiency.

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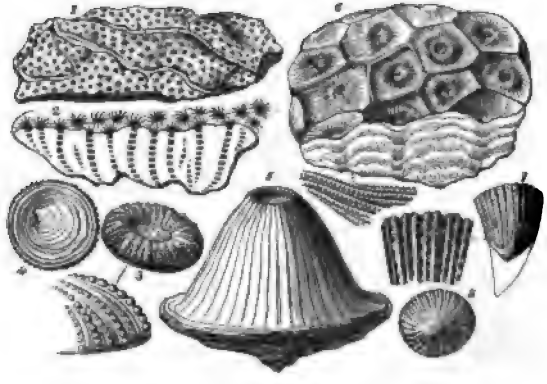
Cœnites juniperinus, Foss. 19. f. 3, may be easily recognized by the curious linear mouths of the cells: this species abounds in the Woolhope limestone of Presteign, and, with C. intertextus (Limaria fruticosa, Sil. Syst.), may be found on almost every fragment of Wenlock limestone: occasionally, a fine large species, C. labrosus, Milne-Edwards, occurs at Dudley.

There are several kinds of tube-corals, such as the Halysites or chain-coral, and certain species of Syringopora, which are abundant. The latter genus is no less curious in its growth than in its structure. When quite young, its divaricating trumpet-shaped tubes creep over the surface of the large corals and shells; and in that state it was figured in the 'Silurian System' as Aulopora serpens* (see Foss. 19. f. 2). It next begins to grow upwards, and each open mouth of the tubes lengthens and becomes a flexuous stem, occasionally throwing out a lateral buttress in concert with its neighbour. These buttresses or buds are hollow, and where they touch each other they coalesce, forming a connecting tube; and the mass, increasing in size upwards, becomes a Syringopora; the

FOSSILS (52). CORALS OF THE UPPER SILURIAN ROCKS.



1. Thecia Swindernana, Goldf. (Porites expatiata, Sil. Syst.). 2. A section magnified. 3. Palæocyclus porpita, Linn. (Cyclolites lenticulata, Sil. Syst.), and a magnified portion. 4. Under side of the same. 5. Ptychophyllum patellatum, Schloth. (Strombodes plicatum, Sil. Syst.). 6. Arachnophyllum typus, M'Coy; and a few of its lamellæ magnified. 7. Petraia bina, Lonsdale, the interior cast, and a portion magnified. 8. End view of the same.

tubes often branching, and uniting with those nearest them, until the coral attains its full size. Syringopora fascicularis, Linn. (S. filiformis?, Sil. Syst.), and S. bifurcata, of which Foss. 19. f. 4, is the lower branched portion, and f. 5 the ascending stems, are common kinds. Aulopora ser-

* Milne-Edwards and Haime have shown these to be the young of Syringopora. Prof. E. Forbes had been of the same opinion for some years, but had not published it.—J. W. S.

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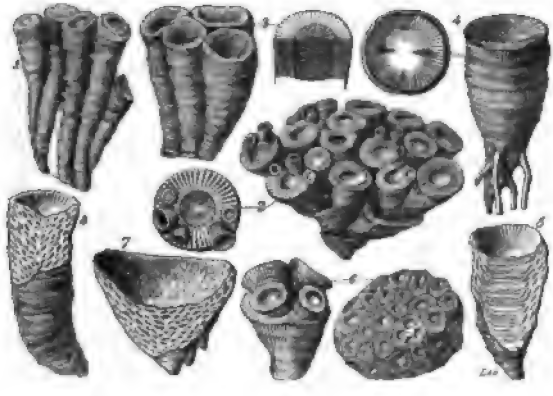
pens, A. tubæformis, and A. conglomerata of the Sil. Syst. are the young or basal portion of one or other of these species. There are one or two rarer forms,—Thecia Swindernana, Foss. 52. f. 1, and Labechia (Monticularia) conferta (Sil. Syst.),—not so obviously belonging to the group we have just noticed, viz. the Zoantharia tabulata of the French authors.

The Palæocyclus of Milne-Edwards is considered by that naturalist to belong to the family Fungidæ, which includes the modern mushroom-corals, and it is the only Silurian, or, indeed, paleozoic coral of the group Aporosa—that group which is the most prevalent in modern seas. Palæocyclus porpita, Linn. (Cyclolites lenticulata, Sil. Syst.), is the one figured, Foss. 52. f. 3, 4; and there are other species, P. præacutus, Lonsdale, and P. rugosus, M.-Edw., at Dudley.

All the cup-shaped corals of the paleozoic series, of which about fifty species occur in Silurian rocks, belong to the section Zoantharia rugosa; distinguished in general, like the other great group (Z. tabulata), by the development of the transverse plates or tabulæ in the body of the coral (see the following woodcut), and including both simple cup-like forms,

FOSSILS (53). CUP-CORALS OF THE WENLOCK LIMESTONE.



1. Cyathophyllum articulatum, Wahl. (cæspitosum, Sil. Syst.) 2. C. truncatum, Linn. (Cyathoph. dianthus, Sil. Syst.); and a single cup, with its marginal disk-buds attached. 3. Strephodes vermiculoides, M'Coy. 4. Omphyma (Cyathoph.) turbinata, Linn., and a view of the cup with its four basal pits. 5. A longitudinal section. 6. Acervularia ananas, Linn., and a cup, natural size, with four young buds. 7. Cystiphyllum Siluriense, Lonsdale. 8. C. cylindricum, Lonsdale.

such as Omphyma (Cyathophyllum) turbinata, Foss. 53. f. 4, Cystiphyllum Siluriense, f. 7, Petraia bina, Foss. 52. f. 7, 8—and branched or composite ones, Cyathophyllum articulatum (cæspitosum), Foss. 53. f. 1, and C. truncatum, f. 2. When such compound corals have grown closely together, so that the separate corallites or cups press one another into an angular form, masses are produced, such as Acervularia ananas,

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f. 6, and Arachnophyllum typus, Foss. 52. f. 6. The latter is now called Strombodes Murchisoni by Milne-Edwards and Haime.

Among these common species, two are remarkable for the mode of propagation of their buds or young corallites.

In Cyathophyllum truncatum, Linn. (C. dianthus, Sil. Syst.), just quoted, the young buds take their origin all round the inner edge of the parent polype-cup (Foss. 53. f. 2), and the eight or ten young corals thus produced quite overtop, and at length cover over, the parent; until, in their turn, they too produce their young clusters; and this process is frequently repeated in the upward growth of the coral. (See the larger figure.)

Another species, so like the former that in some conditions it might easily be mistaken for it, is Acervularia ananas (A. luxurians, Eichwald), described by Fougt* and Linnæus from rocks in Gothland which are now known to be Upper Silurian. A single cup is represented (Foss. 53. f. 6), which has given birth, by fissiparous division, to four young corallites, which take their rise, not from the margin, but from the centre of the old coral; the life of the parent being thus continued in the offspring. (See Lonsdale in Sil. Syst. pl. 16. f. 6.) As a number of these buds grow up together, they stunt each other's growth in a lateral direction, and as the process of multiplication is often repeated, the corals by mutual pressure are forced into an angular form like the cells of a honeycomb; their edges grow together, and the result is a compound mass of stars†. (See the right-hand figure.)

There are several other cup-shaped corals which are frequent in the Upper division, and especially in the Wenlock limestone; but they are not so characteristic as those just mentioned. Omphyma? (Caninia) lata, M'Coy, O. Murchisoni, Milne-Edw., Cystiphyllum cylindricum, Lonsdale, C. Grayi, Milne-Edw., and C. brevilamellatum, M'Coy; Cyathophyllum angustum, Sil. Syst. pl. 16. f. 9, Strephodes trochiformis, M'Coy, S. vermiculoides, Foss. 53. f. 3, Arachnophyllum diffluens (Strombodes, Milne-Edw.), Ptychophyllum patellatum, Foss. 52. f. 5 (a remarkable species, in which the elevation of the centre of the cup is so great, as to give the coral a reversed appearance, the base being nearly flat), Clisiophyllum vortex, M'Coy, and Goniophyllum Fletcheri, M.-Edw., a four-sided coral, very like one found in the Isle of Gothland, Sweden. Some cup-corals also are common to Gothland and Britain, such as Aulacophyllum mitratum, Hising., and Cyathophyllum Lovèni, M.-Edw., besides the two species of the latter genus before mentioned‡; and there are some which extend their range to America.

* Amœnitates Academicæ, vol. i. p. 196, &c.

† The growth and reproduction of corals has of late years been much studied, and well illustrated by Dana, Milne-Edwards, and other naturalists.

‡ So many of the Wenlock corals are found in the limestone of Gothland

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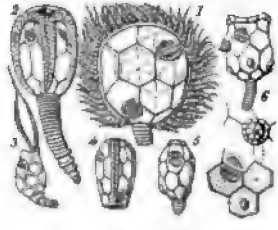
The Ludlow rocks, being for the most part mudstones, do not often contain many corals; but in their calcareous portions, one or other of the species above described occur. Prof. M'Coy has lately added Cyathaxonia Siluriensis to the scanty Ludlow list; it is from Kendal. Stenopora fibrosa, indeed, is very common in the form of an incrusting envelope upon spiral shells, Turbo and Murchisonia (see p. 147, and Foss. 17. f. 8). It was figured in the 'Sil. Syst.' as a species of Alveolites. The Stenopora fibrosa, with Favosites alveolaris, and some few others, seem to have been indifferent to the nature of the sediment they lived upon, for they are found throughout the system. The little Palæocyclus appears to have lived indifferently on a calcareous, muddy, or gravelly bed. The Petraia bina seems to have preferred a muddy base, but most species of this genus are chiefly found in sandstones.

Of Cystideæ the forms are rare, but remarkable and characteristic; the species in the Upper Silurian being all furnished with what Edward Forbes called 'pectinated rhombs.' The fine species figured in Foss. 54. f. 1, has three of these curious markings, the usual number possessed by British Upper Silurian forms, while they are often much more numerous in those few Lower Silurian genera which have them at all. The nature of these rhombs is not yet fully understood. The following species of Cystideæ have been observed at Dudley, and are to be seen in the rich collections of Mr. Gray and Mr. Fletcher of that place:—Pseudocrinites magnificus, f. 1; P. quadrifasciatus, f. 2; P. bifasciatus, and P. oblongus, Forbes*; Apiocystites pentremitoides, f. 4; Prunocystites Fletcheri, f. 3; Echino-encrinites baccatus, f. 5, and E. armatus, f. 6. Under the upper right-hand figure, one of the curious 5- or 6-valved ovarian open-

FOSSILS (54). CYSTIDEÆ OF THE WENLOCK LIMESTONE.



1. Pseudocrinites magnificus, Forbes. 2. P. quadrifasciatus, Pearce. 3. Prunocystites Fletcheri, Forbes. 4. Apiocystites pentremitoides, Forbes.

5. Echino-encrinites baccatus, Forbes. 6. E. armatus, Forbes, with its ovarian pyramid, and rhombs.

ings is shown, and a pair of pectinated rhombs: these last always occur opposite each other on neighbouring plates.

The genus Echino-encrinites, but, of course, with different species, is found in the Lower Silurian rocks of Russia. In North America, the

in Sweden, that the stratum might have been identified by them alone—Heliolites interstinctus, Favosites alveolaris, F. Gothlandicus, and F. cristatus; Cœnites juniperinus, Halysites catenularius, Syringopora fascicularis, Favosites oculatus? (Alveolites repens), Omphyma turbinata, Ptychophyllum patellatum, Acervularia ananas, &c. These species are well figured by Hisinger.

* Memoirs Geol. Survey, vol. ii. pl. 2. pp. 496 *et seq.*

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representative of the Wenlock limestone (the 'Niagara group' of New York) contains some characteristic Cystideæ of similar forms.

The curious fossil, Ischadites Kœnigi, Pl. 12. f. 4, may also possibly belong to this group of animals.

Passing on to the great group of Crinoid animals, which are numerous but rarely perfect in our lower division, we find the Upper Silurian very rich in forms of this class. Many of these are yet undescribed, and we can only, at present, refer to those figured in our Plates 13–15, and to a few other species that have been published in the works of Austin, D'Orbigny*, &c.

By far the commonest fossil of this class is the Periechocrinus moniliformis (Actinocrinus, Sil. Syst.), Pl. 13. f. 1, 2, the long, bead-like stems of which cover the slabs of Dudley limestone, and sometimes attain five feet in length. This and the following species have the arms composed of a double row of plates set side by side:—Dimerocrinites decadactylus, Pl. 13. f. 5; D. icosidactylus, f. 4, a common fossil; three species of the singular genus Eucalyptocrinites, Goldfuss (Hypanthocrinus, Sil. Syst.), found in the Dudley limestone, viz. E. decorus, Pl. 14. f. 2; E. polydactylus, M'Coy, a very large species; and the rare E. granulosus, Lewis, as yet detected only at Walsall in Staffordshire; and lastly, the Marsupiocrinites cælatus, Pl. 14. f. 1. A reduced copy of a perfect specimen of this fossil is given, Foss. 55. f. 1; and at f. 3 the same species is drawn without the arms, but showing the long proboscis inserted into the shell of a mollusk—Acroculia Haliotis. This shell is better figured in Pl. 24. f. 9.

From the very frequent occurrence of the same shell, tightly embraced by the arms of this crinoid, and from the fact that the mouth of the shell is always turned downwards over the proboscis, it is inferred, that it was the habitual food of the encrinite. This has been long observed by Mr. John Gray of Dudley, who has dissected many specimens from the stone, and they are to be seen in his collection. It has also received confirmation from the American naturalists, Yandell and Shumard, who observed the same habit in several of the Silurian crinoids of America.

Of those species which have only a single row of joints in each arm, Cyathocrinus tuberculatus is the most common. It occurs of all sizes, from the minute specimen represented, Pl. 14. f. 6, to much larger forms than f. 5. Cyathocrinus tesseracontadactylus (C. simplex, Sil. Syst.), f. 4, and C. Orbignyi, M'Coy, are rarer forms; the former being found also in Gothland. C. goniodactylus, f. 3, C. arthriticus, f. 7, and C. capillaris, Pl. 15. f. 3, are common Dudley fossils. Ichthyocrinus pyriformis often grows larger than it is represented in Pl. 14. f. 8; and this

* Austin, Monograph of the Crinoidea, 1844; D'Orbigny, Prodr. de Paléontol. Universelle, 1849, p. 45, &c.

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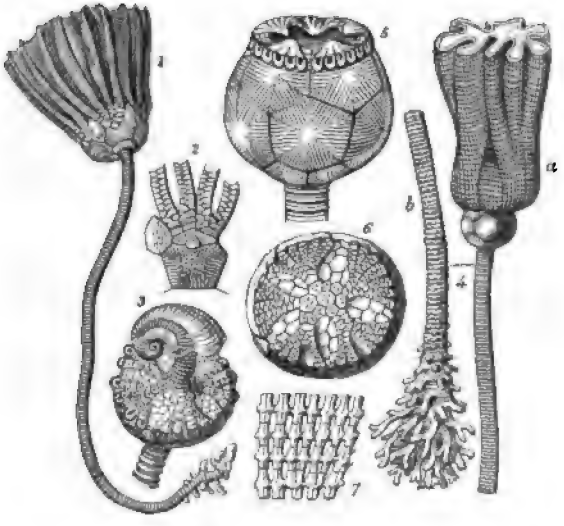
species extends its range to North America. Platycrinus* (Actinocrinus?) retiarius, Pl. 14. f. 9, when perfect, has a long stem with many auxiliary arms. Fine specimens are in the Museum of Practical Geology.

Enallocrinus punctatus, Hisinger, which occurs both in England and Sweden†, is frequently found on Wenlock Edge.

Glyptocrinus? expansus (Actinocrinus, Sil. Syst,), Pl. 15. f. 1, is perhaps one of the most stately species, conspicuous for the size to which it grows, and for the numerous plates of which its cup is composed.

Lastly may be noted a very common Wenlock fossil, Crotalocrinus rugosus, Foss. 55. f. 4–7, whose structure is, perhaps, more remarkable than that of any other Silurian crinoid.

FOSSILS (55). CRINOIDEA OF THE WENLOCK LIMESTONE.



1. Marsupiocrinites cælatus. 2. Magnified base of the arms. 3. Proboscis of the same inserted in the shell of Acroculia Haliotis. 4. Reduced figure of Crotalocrinus rugosus; the bag-like cluster of arms surmounting the small, round 'pelvis.' 5. The latter, of the natural size, with the stomach plates stripped off, and showing the base of the many-fingered arms. 6. The flat stomachal surface, showing also the branching of the arms from their bases. 7. A part of the reticulate congeries of fingers, each joint being anchylosed to its neighbour on either side.—[J. W. S.]

In most Encrinites the arms issue immediately from the edge of the pelvic‡ cup, commencing with a single joint, and soon branching into

* Prof. de Koninck, in a recent survey of the British Silurian Crinoidea at Dudley, has decided that there are several carboniferous genera among them.

† See Hisinger, Lethæa Suecica, pl. 25. f. 2.

‡ A better nomenclature than that of Miller's—basal plates, radial and interradial plates, &c.—is now adopted. See Prof. M'Coy in Pal. Foss. Woodw. Mus.; De Koninck et Le Hon, in 'Les Crinoïdes Terr. Carb. Belgique,' 1854.

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two, three, or four; the subdivision varying in different species. But in this wonderful encrinite, the upper edge of the pelvis is seen to be surmounted by at least twenty or twenty-five arm-joints, instead of the usual five; and when the specimens have lost all but the pelvis and these lower joints, the latter are seen (Foss. 55. f. 5) to have each a perforation in their middle, as in the arm-joints of all other crinoids. These multitudinous arms soon divide, and subdivide again and again, the several branches lying close, side by side, and leaving scarcely any free space between them.

Each joint gives off from either side a small lateral process, f. 7, which unites with that of its next neighbour, and this is continued through the whole extent, so that the several joints of the contiguous rays are all securely fixed to each other. Instead, therefore, of a star of free and waving arms, a deep, wide funnel is formed, like a wicker basket; or rather (as the joints are all of equal length, and the lateral processes range in continuous transverse lines), the texture is like that of a piece of the coarsest woven serge or canvas, f. 4 *a*. This curious funnel of anchylosed arm-joints, therefore, was either flexible, or grew in a lobed and puckered form*. But although, as before said, the numerous arms seem to start at once from the pelvis, their real origin is on the ventral surface further inward—see f. 6—where they commence with single joints, as in other crinoids, and are clothed with short tentacles to their very base. This surface is but rarely visible, the usual appearance of the cup being that which is seen in f. 5, and in Pl. 13. f. 3, which figures are of the natural size. The cup consists of fifteen plates. The stem, f. 4 *b*, was long ago figured by Parkinson in his 'Organic Remains†.' It is made up of close joints, each with a row of tubercles, which are perforated, the hole communicating with the central canal of the stem. Near the root, these tubercles lengthen out into cylindrical tubular processes, which attach the animal to shells and corals. The cabinets of my friends, Mr. Fletcher and Mr. Gray, furnished the materials to Mr. Salter for the illustration and description of this remarkable fossil.

Asteriadæ, or starfish, are by no means rare in the Upper Silurian; four species, which are here figured, having been long ago found in the Ludlow rocks of Kendal. The most common is Palasterina primæva, Foss. 56. f. 1. Palæaster Ruthveni, f. 3, and Palasterina hirudo, f. 2, are less abundant. The rare fossil, Protaster Sedgwicki, f. 4, was thought by Prof. Forbes to be closely related to certain species of the group of Euryales, now inhabiting the northern seas; but better specimens of the genus

* Since the first edition of this book was published, we have seen Müller's beautiful figures of a very similar genus (Anthocrinus Lovèni) from the Isle of Gothland. In all probability there were in our species, as in his, five reticulate arms, overlapping each other, and highly convoluted, but not forming a continuous funnel. Ueber die Bau der Echinodermen, tab. 8, Berlin, 1854.

† 'Turban, or Shropshire Encrinite,' vol. ii. pl. 15. f. 5. p. 193.

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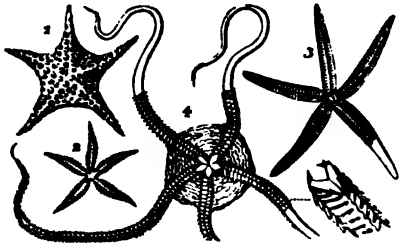
since obtained (p. 141), show it to have been an abnormal form of the Ophiuridæ, from which it differs in having a double, instead of only a single row of plates above and below. This genus Protaster, which first appears in the Lower Silurian strata, has been found abundantly in the fine grey flagstone of the Lower Ludlow rock. In Shropshire, the P. Miltoni, nearly a foot wide from tip to tip of the rays, and a small, graceful species, P. leptosoma, have been discovered within the last year*; together with four or five species of Palæocoma, a starfish which greatly resembles the common red Bird's-foot sea-star (Palmipes roseus) of our coasts. One species, Palæocoma pyrotechnica, has stiff club-shaped spines like those of the living cushion-stars. Lastly, there is a starfish in the Dudley limestone, named Lepidaster Grayii† by Prof. Forbes, more crinoidal in its aspect than any existing species.

FOSSILS (56). UPPER SILURIAN STARFISHES.



1. Palasterina primæva, Forbes. 2. P. hirudo, Forbes. 3. Palæaster Ruthveni, Forbes. 4. Protaster Sedgwicki, Forbes.

All from the Upper Ludlow rocks in the neighbourhood of Kendal. First found by Professor Sedgwick.

I have thus dwelt particularly on a few of the radiate animals, because they present us with some new or little-known characteristics of the Silurian rocks. The remaining groups, Mollusca, Worms, and Crustacea, do not call for much detail.

Brachiopod shells, though not in such great preponderance, nor so numerous in species, as in the Lower Silurian rocks, are yet very abundant. Pentameri are still present, but mostly distinct from the Llandovery species. But whilst the Orthides are in much less quantity than in the inferior zones, the Rhynchonellæ and Spirifers occur very frequently; and of Lingula there are decidedly fewer kinds than in the Lower Silurian.

Several characteristic Brachiopods have been quoted as ranging from the Lower to the Upper Silurian, such as Orthis elegantula, O. biforata, and O. biloba; the first of these being equally abundant in both divisions. Though also occurring in both, Strophomena depressa and S. Pecten, Leptæna transversalis, Atrypa marginalis and A. reticularis, are far more abundant in the Wenlock than in any of the lower strata, except in the Llandovery rocks. The last-named ranges no lower than the

* Salter in Ann. & Mag. Nat. Hist. 1857, vol. xx. p. 330.
† Mem. Geol. Surv. Decade iii. pl. 1.

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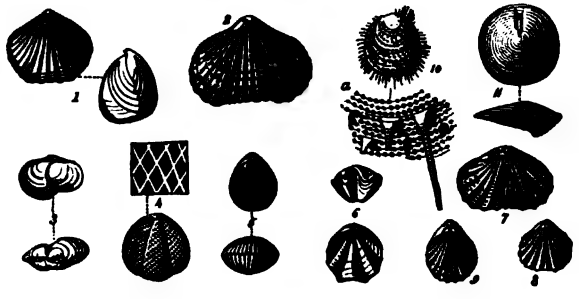
Llandovery strata; and the same may be said of Spirifer trapezoidalis, Dalm., S. plicatellus (radiatus, Sil. Syst.), Pl. 21. f. 2, Retzia cuneata, and Rhynchonella borealis; but they are rarer below the Wenlock shale. These species have a wide geographical range. In Chapters 6 and 7, thirty species are enumerated from the various strata of the Upper Silurian rocks, among which Leptæna transversalis, Strophomena euglypha, Spirifer elevatus, S. plicatellus, and Pentamerus galeatus are most characteristic of the Wenlock strata; the Rhynchonella Wilsoni, R. nucula, R. navicula, Orthis lunata, and Chonetes lata, chiefly distinguish the Ludlow rocks. Yet in some localities, the Rhynchonella navicula and the Chonetes lata are prevalent in the Wenlock strata—the former near Builth, the latter on the W. coast of Ireland.

The species above enumerated are drawn in Plates 20–22. There are, however, several others which must be noticed. Among the rarer Wenlock species may be reckoned,—Discina (or Orbicula) Morrisii, and D. Verneuilii of Davidson, D. Forbesii (Foss. 57. f. 11), and Crania implicata, Pl. 20. f. 4. These are species of genera existing at the present day. Discina rugata, Pl. 20. f. 1, 2, and D. striata, f. 3, are common Ludlow forms.

Siphonotreta Anglica, Foss. 57. f. 10, is a rare fossil; the genus being characteristic of the lowest Silurian rocks in Russia. Even the genus Obolus, also very characteristic of the same Lower Silurian near St.

FOSSILS (57). UPPER SILURIAN BRACHIOPODA.



1. Rhynchonella nucula. 2. R. Lewisii, Davidson. 3. R. Grayii, Davidson. 4. R. Capewellii, Davidson. 5. R. Bouchardi, Dav. 6. R. Barrandii, Dav. 7, 8. Retzia Salteri, Dav. 9. Var. of the same (R. Baylii, Dav.). 10. Siphonotreta Anglica, Morris; *a*, portion of the surface, with the annulated spines, magnified. 11. Discina Forbesii, Dav.

Petersburg, has, through the acumen of Mr. T. Davidson, been recognized in the Wenlock shale of Dudley and Walsall. The two British species, Obolus transversus and O. Davidsoni, Salter, are both larger species than those of Russia*. With such constantly augmenting data

* They are figured and described as Upper Silurian fossils in Mr. Davidson's Monograph (Introd. p. 136), Palæontographical Society, for 1854.

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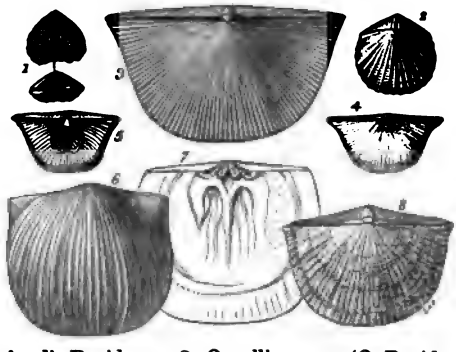
for connecting them, it is obviously impossible to divide the Silurian rocks into two natural systems.

Spirifer trapezoidalis, Dalm., is frequent in the Woolhope limestone and Lower Wenlock shales. S. sulcatus, Hisinger, is a small species common on Wenlock slabs; Athyris Circe, Barr., a Bohemian fossil, occurs with the common A. tumida at Walsall; Retzia Salteri, Foss. 57. f. 7, and its varieties, f. 8, 9; Rhynchonella Lewisii, f. 2, and R. Bouchardi, f. 5, are common Wenlock species; R. Barrandii, f. 6, R. Capewellii, f. 4, and R. Grayii, f. 3 (a strange twisted species), are rare Dudley fossils. R. nucula, f. 1, is the commonest of all the Rhynchonellæ of the Upper Ludlow rock. Imperfect specimens of it are figured in Pl. 22. f. 1, 2.

Three Pentameri only were formerly described from the Upper division, viz. P. linguifer, P. galeatus, and P. Knightii (see Pls. 21, 22). To these may now be added P. liratus, Foss. 14. p. 100, found in the Woolhope limestone, which may be considered as strictly a transition species, occurring in the very lowest beds of this division, and in the uppermost strata of the Llandovery formation, at May Hill, Gloucestershire, at Presteign, and also in Pembrokeshire.

Some species of Orthis have been already quoted, Chap. 6, as very

FOSSILS (58). UPPER SILURIAN BRACHIOPODA.



1. Orthis Bouchardi, Davidson. 2. O. calligramma (O. Davidsoni, de Vern.). 3. Strophomena Pecten, Linn. 4. S. funiculata, M'Coy. 5. Interior of the same. 6. S. imbrex (Pander and Davidson). 7. Interior of dorsal valve of the same. 8. S. antiquata, full-grown (half natural size).

common in the Wenlock and Dudley limestone. O. Bouchardi, Foss. 58. f. 1, O. Lewisii, Davidson*, and O. æquivalvis, Davidson, are rare in the

* Bull. de la Soc. Géol. de France, 2nd series, t. v. p. 309, 1848. This memoir contains figures of all the British Upper Silurian species then known, including a great many not before described. The reader of it will find a single Productus described there. As this is a genus never found below the limits of the Devonian strata, it is well to note that Mr. Davidson now believes it to be an imperfect Strophomena depressa, a common Silurian species.

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same formation; and so is O. calligramma, adverted to at p. 209, if the shell here figured, Foss. 58. f. 2, be not a distinct species (O. Davidsoni), as De Verneuil and M'Coy suppose.

Strophomena antiquata, Foss. 58. f. 8, grows five or six times the size of the figure in my original work (see Pl. 20. f. 18). Strophomena funiculata, f. 4, and S. imbrex, f. 6, 7, are common Wenlock species. S. corrugata, Portlock, is a beautiful but rare Wenlock shell, which has been already cited in the Lower division, where it is plentiful. S. Pecten, f. 3, though common both in Lower and Upper Silurian, escaped notice when the 'Silurian System' was published. S. applanata, Salter, is a small species resembling the last, which occurs sparingly in both divisions.

Lingula Lewisii, Pl. 20. f. 5, is one of the commonest species of the Middle Ludlow or Aymestry rock; and L. cornea, Pl. 34. f. 2, abounds in the Tilestone of the Upper Ludlow. They are both well-marked species, and, with the small but characteristic L. lata of the Lower Ludlow rock, are the only species of the genus yet described from the Upper Silurian of Britain. There is another long-oval species in the Wenlock shale and Woolhope limestone, now well known in cabinets under the name of L. Symondsii, and so called after my esteemed friend the Rev. W. Symonds, of Pendock, Ledbury. It is a common species at Malvern and Buildwas in Shropshire.

The Lamellibranchiate bivalves, though numerous in species, have not yet been fully described. They consist chiefly, as Prof. Phillips has pointed out*, of one or two families closely related, and which are represented by the living forms, Mytilus, Arca or Nucula, and Avicula. When strictly defined, the more modern genera Pullastra, Mya, Cypricardia, and Cardium, to which several of these forms were referred in the original Silurian work, are found not to have existed in these early geological times.

Forms of the genus Pterinea (Avicula, Sil. Syst.) abound. P. retroflexa, Pl. 23. f. 17, a species subject to great variation, has already (pp. 109, 134, &c.) been quoted from various strata. P. Sowerbyi, f. 15 (Avic. reticulata, Sil. Syst.), characterizes the Aymestry limestone, whilst P. lineatula (Avic. lineata, Sil. Syst.), f. 16, is very frequent near Ludlow. Besides these common species, Prof. M'Coy has enumerated several others; viz. P. Boydii, P. demissa, P. pleuroptera, and P. subfalcata of Conrad, and P. tenuistriata, Foss. 59. f. 5. The last three are, it is believed, also found in Lower Silurian rocks in Wales and Westmoreland. Others are Upper Silurian forms only; such as P. hians, M'Coy, an Aymestry rock fossil, and P. asperula, f. 4, a fossil from the Wenlock shale at Builth. A common Wenlock species, doubtfully referable to

* Mem. Geol. Surv. vol. ii. pt. 1. p. 264.

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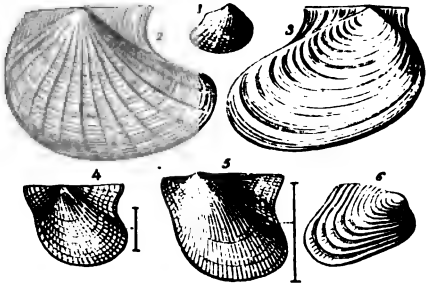
this genus, is the P. planulata, Conrad, Foss. 59. f. 6. Many species, however, of this age, particularly those from Pembrokeshire and Ireland, are, as yet, imperfectly known. The district of the Dingle, in Ireland, for example, is rich in fossils of this group. Of these, P. orbicularis, M'Coy, is one of the largest and most plentiful. P. posidoniiformis and P. fimbriata are described by the same author; and there are other species, with several fine varieties of the common P. retroflexa, in that prolific locality.

FOSSILS (59). UPPER SILURIAN LAMELLIBRANCHIATA.



1. Pleurorhynchus sequicostatus, Phill. 2, 3. Avicula Danbyi, M'Coy. 4. Pterinea asperula, M'Coy. 5. Pter. tenuistriata, M'C. 6. Pter.? planulata, Conrad.

Other large species, more resembling Avicula, or Aviculopecten, such as A. Danbyi, Foss. 59. f. 2, 3, and A. ampliata, Phillips, occur in the Upper Ludlow rock; whilst Avicula mira, Barrande, a beautifully reticulated species, which is common at Dudley, is identical with one from the Upper Silurian of Bohemia.

Next in importance are the mytiloid shells, or Modiolopsis, as the genus is now called*, which contains several species. Thus, M. complanata, Pl. 23. f. 1, is an Upper Ludlow fossil; M. Nilssoni, Foss. 60. f. 8, is both a Wenlock and Ludlow species; and M. platyphyllus, f. 7, is characteristic of the uppermost Ludlow beds, where it occurs with some other forms, now referred by Prof. M'Coy to his new genus Anodontopsis. To this group, which contains the more circular species of the genus, belong M. quadratus and M. ovalis, Salter, M. angustifrons, M'Coy, M. lævis, and M. (Anodontopsis) bulla, Foss. 60. f. 5. They are all species of the Ludlow rock. Mytilus exasperatus, Phillips, and Modiola antiqua, Pl. 23. f. 14, are Wenlock shale fossils; the latter being common. Mytilus mytilimeris, Foss. 60. f. 6, is also plentiful in Wenlock shale. Goniophora cymbæformis, Pl. 23. f. 2, seems nearly allied to Mytilus, and is one of the most abundant Upper Ludlow shells. Certain forms, less evidently related to this family, have been termed Orthonota by some authors, and Sanguinolites by others. They are thin shells,

* There does not appear, however, to be any decided character to separate these shells from the Modiolæ of our own day.—J. W. S.

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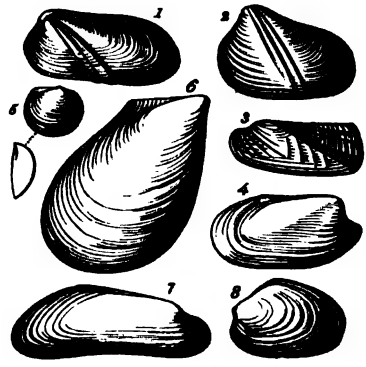
without hinge-teeth, and outwardly much resemble Mya, Panopæa, &c., to which they are not at all allied in reality. Orthonota semisulcata (Modiola, Sil. Syst.) is one example from the Ludlow rocks, not figured in this work; and a new species, O. prora (Foss. 60. f. 4), is one of the most frequent fossils in the Tilestones of Westmoreland. Other species referred to this genus in the publications of the Geological Survey* differ

FOSSILS (60). UPPER SILURIAN LAMELLIBRANCHIATA.



1. Grammysia cingulata, Hising. 2. G. triangulata, Salter. 3. Orthonota angulifera, M'Coy. 4. O. prora, Salter (O. semisulcata, M'Coy). 5. Anodontopsis bulla, M'Coy. 6. Mytilus mytilimeris, Conrad. 7. Modiolopsis platyphyllus, Salter. 8. M. Nilssoni, Hisinger.

still more widely in outward appearance from the Modiola, to which they are nevertheless believed to be related. They are abundant in the Ludlow rocks, especially O. amygdalina, Pl. 23. f. 6, and its variety, O. retusa, f. 7. This species often covers the surfaces of the uppermost stratum of the Upper Ludlow rock, to the exclusion of all other fossils, and with it, more rarely, occur O. impressa, Pl. 23. f. 3, and O. undata, f. 4. Orthonota rotundata (Mya, Sil. Syst.), f. 5, is characteristic of the Aymestry limestone; but O. solenoides, f. 9, and O. rigida, f. 8, are more common in the Lower Ludlow. O. angulifera, M'Coy, Foss. 60. f. 3, is an ornamented species, rare in the Ludlow rocks of Westmoreland, and looking like the Goniomya V-scripta of the oolite rocks.

Grammysia, De Verneuil, is a genus resembling the shells last mentioned, but easily recognized by its deep furrows on the valves. G. triangulata, Foss. 60. f. 2, is a typical Tilestone fossil, and G. cingulata, f. 1, as well as G. extrasulcata, Salter, are found with it, both in S. Wales and Westmoreland. The last-named is equally common in other Upper Silurian strata (Wenlock), at Dudley, Usk, and near Llandeilo, and is also found in Gothland, Sweden, and Norway. It appears to have flourished best on sandy ground; a condition apparently most favourable to the Lamellibranchiata in general.

Cardiola interrupta, Pl. 23. f. 12, is one of the most abundant bivalves in the Wenlock and Ludlow shales (see p. 141). On the Continent it is

* Memoirs, vol. ii. pt. 1. p. 360.

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also found in Upper Silurian strata, but does not extend its range upward into the Devonian rocks. Cardiola fibrosa, f. 11, is a Lower Ludlow fossil, and C. striata (Cardium striatum, Sil. Syst.), f. 13, is also to be referred to the same genus. The shells of the genera Nucula and Arca, in which the hinge-line is beset with close-ranged teeth, are very numerous in individuals, though of few species, in the Upper Silurian. Some of them may be true Nuculæ, or even belong to the genus Leda, Forbes; others will fall (see p. 213) into the genus Ctenodonta*, proposed in 1851 for those paleozoic Nuculæ with an external ligament. Nucula Anglica, Pl. 23. f. 10; N. (Arca) primitiva, Phillips; N. Edmondiæformis, M'Coy, and N. (or Ctenodonta) subæqualis, M'Coy, Pl. 10. f. 7, are Upper Ludlow shells, though most of them had an earlier origin, whilst Nucula sulcata, Hisinger (Mem. Geol. Surv. vol. ii.), ranges throughout the Upper Silurian. The genus Cucullella, distinguished by a strong internal ridge, contains several Ludlow species. C. antiqua, Pl. 34. f. 16, C. Cawdori, f. 3, and especially C. ovata, f. 17, are common shells in the uppermost Ludlow (Tilestones, Sil. Syst.). C. coarctata, Phillips, is found in great plenty in the Ludlow rocks of Pembrokeshire, and occurs also in the Wenlock shale. The genus Cleidophorus, which has no teeth in the hinge, is otherwise much like Cucullella. C. planulatus, Conrad, is found, according to M'Coy, in Wenlock shale.

Lyrodesma (Actinodonta) cuneata, Phill., seems to connect these Arca-like shells with the Mytilidæ or Mussel family. This species is found by hundreds in the shales of Marloes Bay—not, however, in the Upper Silurian, as formerly supposed, 'Memoirs of the Geol. Survey,' vol. ii., but in the Llandovery rocks (see p. 203).

Lastly, as a representative of the Cardiaceæ, we have one small species of Pleurorhynchus; a genus which, as we have before seen, p. 214, commenced existence in the lower division. P. æquicostatus, Foss. 59. f. 1, is a miniature example of it, found at Wenlock and Woolhope. In North America, larger species of this genus occur in Upper Silurian rocks.

Lamellibranchiate shells are far more frequently met with in the Upper Silurian strata than in the Lower; a fact indicated long ago by the organic remains figured in my former work, and confirmed by subsequent observations. Out of forty-five species quoted in Prof. Phillips's detailed memoir†, published nine years after the 'Silurian System,' five or six only are found in the Caradoc sandstone and Llandeilo flags. Prof. M'Coy, in his recent catalogue of the Woodwardian Museum, enumerates twenty-three species as belonging to the lower group, while he describes fifty from the Upper Silurian; as many as twelve being common to both

* Rep. Brit. Assoc. 1851, Trans. Sect. p. 63. Tellinomya of Hall proves to be the same genus, though the name is not applicable. See his Description of New Palæoz. Foss., Albany, 1857, p. 141.

† Mem. Geol. Surv. vol. ii. pt. 2, 1848.

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divisions. Major-General Portlock has, indeed, described many Lower Silurian forms of this group from Ireland, but an inspection of the Museum of the Geological Survey, and of numerous private collections, will convince any one, that the larger proportion in species is still on the side of the Upper Silurian rocks; whilst the individuals in them are unquestionably more numerous.

The suggestive remark of Prof. Phillips must here be noticed, that the families to which the Silurian Lamellibranchiata generally belong are those which occur at the junction, so to speak, of the Monomyarian and Dimyarian groups. Mytiloid, Nuculoid, and Aviculoid shells, with few additions, were, therefore, the representatives of this order in the Silurian seas.

Gasteropod mollusca, or univalve shells, are spread throughout the Upper Silurian, but seldom form a conspicuous feature. The Wenlock limestone, however, is neither poor in species nor individuals, though several are yet unpublished. Among them, Euomphalus occupies a marked place; four species especially swarming in certain localities, viz. E. discors, Pl. 24. f. 12, E. rugosus, f. 13, E. funatus, Pl. 25. f. 3, and E. alatus, f. 4. A species also very like E. centrifugus, Wahlenberg, not unfrequently occurs with them. Euomphalus sculptus, f. 2, which appears to be only a variety of E. funatus, is found as frequently in the Llandovery as in Wenlock rocks. The E. alatus, f. 4, is chiefly a Wenlock shale species, and occurs of the largest size in the calcareous slates of the Dingle promontory in Ireland. It is there associated with several other species, particularly the large E. lautus and E. tricinctus, M'Coy. E. carinatus, Pl. 24. f. 11, is more characteristic of the Middle Ludlow or Aymestry rock. Of all these species, E. funatus is by far the most common, and has the greatest vertical range. Its concentric operculum is often met with, and helps to show the near relation of the genus to Delphinula, as above stated (p. 214, Note).

Turbo cirrhosus, Pl. 24. f. 10, often occurs in the Wenlock shale, and the T. Williamsii, Pl. 34. f. 14, together with two other species of the genus mentioned in p. 216, are frequent in the Upper Ludlow, especially in the tilestones. This last rock is also crowded with the Trochus? helicites, Pl. 34. f. 12, 13, a shell which is referred to that genus with great doubt, since it looks more like a land-snail in outward form. It probably belongs to a distinct genus (Platyschisma of M'Coy), and is in no way allied to the group in which it now stands. Trochus cælatulus, M'Coy, is a rare species from the Woolhope limestone; and Turbo (Littorina) undifer, M'Coy, is a small species of the Aymestry rock.

The Turritellæ, Sil. Syst., of the uppermost Ludlow rocks have been already referred to the genus Holopella, p. 214; H. obsoleta, Pl. 34. f. 11, H. gregaria, f. 10 *a*, and H. conica, f. 10, being very frequent fossils in this stratum in Westmoreland, Shropshire, and S. Wales. Prof. M'Coy

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has distinguished another small species, H. gracilior, from the Wenlock shale of Llangollen. Loxonema sinuosa, Pl. 24. f. 3, and L. elegans, M'Coy, are chiefly Ludlow rock species. The latter is a fine shell, two inches long, and is frequent both in the Wenlock and Ludlow shales.

Spiral shells with notched apertures, Pleurotomaria and Murchisonia, are common. Murchisonia corallii, Pl. 24. f. 7; M. articulata, f. 2, and M. torquata, M'Coy, are slender turreted forms in the Ludlow rocks. M. cingulata, Hisinger, three inches long, from Aymestry, is found also in Gothland. M. Lloydii, Pl. 24. f. 5, abounds in the Middle and Lower Ludlow, and is frequent in Wenlock limestone. Pleurotomaria balteata, Phillips (Mem. Geol. Surv. vol. ii. pt. 1. pl. 15), is another interesting Wenlock form; and P. undata, Pl. 24. f. 6, is from the Lower Ludlow, where some other large species, yet unpublished, are also found. Acroculia (Nerita) Haliotis, Pl. 24. f. 9, and A. prototypa, f. 8, are exceedingly abundant, the first especially, in Wenlock limestone, and also in the Upper Silurian of Bohemia. These mollusks seem to have formed the chief diet of the numerous encrinites of the period, both in England and America (see p. 246). Natica? parva, Pl. 25. f. 1, and a few other shells complete the list of published species; but many others, I am assured by Mr. Salter, remain to be described.

One or two Pteropods only have yet been detected, nor do they seem to be so plentiful as in the lower rocks. Theca Forbesi of Sharpe, a species very like that figured in Foss. 39. f. 1, p. 218, and T. anceps, Salter, are Wenlock shale species, and the former is also common in the Upper Ludlow rock. Besides these, Conularia seems to be the only British Upper Silurian pteropod, unless the Cyrtolites lævis, Pl. 25. f. 9, may be considered a member of this group. The beautiful and variable Conularia Sowerbyi (C. quadrisulcata, var., of my former work), Pl. 25. f. 10, is often found in Wenlock limestone, and occurs with a rarer species, C. subtilis, Salter, in the Ludlow rocks of Westmoreland.

Bellerophons are frequent. B. dilatatus, Pl. 25. f. 5, 6, is one of the largest univalves in the Ludlow and Wenlock rocks. The broad, expanded mouth is often three inches wide, and is sometimes furnished with radiating ribs (see the figure),—at other times smooth, Foss. 39. f. 8, in Chap. 9. B. Wenlockensis, Pl. 25. f. 7, is very characteristic of the strata implied in its name. B. expansus, f. 8, is equally so of the Upper Ludlow rock. The latter, and B. Murchisoni?, Pl. 34. f. 19, B. carinatus, f. 8, and B. trilobatus, f. 9, generally of small size, are most abundant everywhere in the Upper Ludlow rock.

Of the Cephalopods which chiefly typify the Upper Silurian strata, it is unnecessary to repeat what has been said of them in describing the Wenlock and Ludlow formations; the species which most abound have already been enumerated (see pp. 126, 141, &c.). It may, however, be noted, that some of these forms are specially characteristic of particular

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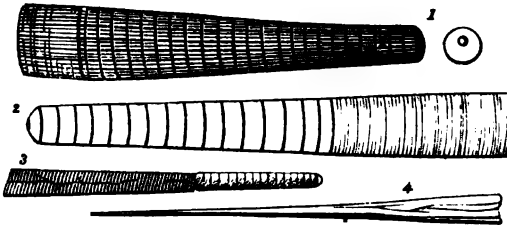
strata. Thus, the thin-shelled species of Orthoceras—O. subundulatum and O. primævum, here figured, are the most frequent shells of the Wenlock shale; O. annulatum, Pl. 26. f. 1, and its variety, fimbriatum, f. 2, is a well-known Wenlock limestone species; O. filosum, Pl. 27. f. 1 (Foss. 61.

FOSSILS (61). UPPER SILURIAN CEPHALOPODS.



1. Orthoceras filosum. 2. O. Ludense. These species are figured from specimens two feet in length. 3. O. subundulatum, Portlock (Cressis Sedgwicki, Forbes). 4. O. primævum, Forbes. The two latter are usually 8 or 9 inches long.

f. 1), O.? perelegans, Pl. 29. f. 5, 6, and O. dimidiatum, Pl. 28. f. 5, are common Lower Ludlow fossils; O. Mocktreense, Pl. 29. f. 2, is a Middle Ludlow or Aymestry species; while O. Ludense, Foss. 61. f. 2, and Pl. 28. f. 1, O. angulatum, f. 4, O. ibex, Pl. 29. f. 3, and especially O. bullatum, f. 1, are frequent Upper Ludlow forms.

Orthoceras nummularium, Pl. 26. f. 5, O. excentricum, Pl. 27. f. 3, O. canaliculatum, Pl. 28. f. 3, are rarer Wenlock species; whilst O. distans, Pl. 26. f. 4, O. subgregarium, Pl. 27. f. 2, and O. imbricatum, Pl. 29. f. 7, are among the less abundant Ludlow fossils.

Orthoceras tracheale, Pl. 34. f. 6, and O. (Tretoceras?) semipartitum, f. 5, though not very common, are characteristic of the uppermost Ludlow or tilestones; as well as O. bullatum, Pl. 29. f. 1, which must also again be noticed, as it occurs in the greatest abundance in every locality of the Upper Ludlow rock, and by inadvertence has been omitted from the list in p. 147.

The same distribution is observable in the other genera; for while certain species of Phragmoceras and Lituites are peculiar to the Wenlock, or the Lower Ludlow, but few range throughout. Phragmoceras ventricosum*, Pl. 32, which has been already mentioned, is, however, one of these last; it is frequent at Malvern, in Wenlock limestone, and also at Leintwardine, Shropshire, in Lower Ludlow; where also the P. (Orthoceras) pyriforme, Pl. 30. f. 1–3, abounds. This species, being straight instead of curved, has usually been regarded as a distinct genus, Gomphoceras. Phragmoceras arcuatum, Pl. 31. f. 3, and P. intermedium, Pl. 30. f. 4, are also Lower Ludlow forms. P. nautileum, Pl. 31. f. 1, 2, and P. compressum, f. 4, are found in Wenlock shale; the last is even a Llandovery fossil.

* This fine Silurian species can scarcely be the Orthoceras ventricosum, Steininger.

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Lituites articulatus is found both in Wenlock and Ludlow rocks; L. Biddulphii, Pl. 31. f. 5, in Wenlock limestone. Lituites giganteus, Pl. 33. f. 1, 2, 3, is one of the finest fossils from Leintwardine and Malvern; and L. tortuosus, of which a fragment is figured, f. 4, is found in the black nodules of the Wenlock shale near Welshpool, and also at Dudley.

The curious genus Ascoceras, of which M. de Barrande has described several species from the Bohemian basin, has been found in the uppermost Silurian rocks of Britain. The species differs but little from the

FOSSILS (62). AN UPPER LUDLOW CEPHALOPOD.

Ascoceras Barrandii, Salter (Quart. Geol. Journal, 1856, vol. xii. p. 291).

From near Usk, Monmouthshire, in Upper Ludlow rock.

common Bohemian form; it has been called A. Barrandii by Mr. Salter. There are specimens from Usk, Ludlow, and Malvern in the Museum of Practical Geology; and it may prove to be common. This fossil seems more nearly allied to the curious genus Tretoceras above mentioned (p. 220: Diploceras, in the former edition) than might be at first supposed.

To complete the catalogue of the Upper Silurian fauna, a brief sketch must be given of its annulose animals, the worms and crustaceans, as well as of the few remains of fishes which have been discovered.

Cornulites serpularius (see Pl. 16. f. 3–10) is still, as in the Llandovery rocks, the principal annelide; and, though more frequent in the Wenlock limestone, is not rare in the Ludlow rocks. The finest specimens are from the Wenlock limestone of Ledbury; but at Dudley Cornulites are found attached to shells, in groups of three or four together, like Serpulæ, and they occur in profusion on the hard and sea-worn surfaces of Ludlow rock at Marloes Bay in Pembrokeshire, in masses a foot in diameter. Tentaculites ornatus, Pl. 16. f. 11, abounds in the Dudley limestone; whilst a small species, T. tenuis, f. 12, occurs in the Upper Ludlow rock. The place of the latter is sometimes taken by a form so like T. Anglicus of the lower division, that it may possibly be a variety only; in which case we gain another characteristic fossil for uniting the two groups. This Tentaculite is plentiful, like the Cornulite, in the sandy Ludlow rocks of Marloes Bay and Freshwater, Pembrokeshire.

Other annelides (Serpulites, Sil. Syst.) are very common in the Ludlow rock. They are flattened tubes, thick at each projecting edge; sometimes shelly, but at other times corneous, or even membranous on the sides.

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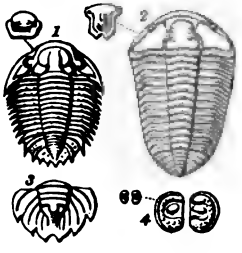
Serpulites longissimus, Pl. 16. f. 1, grew to a length of twenty inches, measured round its long spiral curve. It is one of the type fossils which most attracted me when I first traced the range of the Upper Ludlow rock. Greyish-blue portions of it are found in that band over great distances throughout the Silurian region, and the small shining fragments are often mistaken for remains of fish. S. dispar, Salter, from Kendal, the tube of which has remarkably thin sides, is figured in the work descriptive of the Woodwardian Museum. Trachyderma coriacea and T. squamosa of Phillips* are wrinkled tubes of these creatures, frequent in the Ludlow rocks of the original Silurian region, and are occasionally found in an upright position in the bed. A few other species are found in the Wenlock strata, and the stratum which I formerly distinguished as the Fucoid bed of Ludlow (p. 147). It appears to contain no remains of sea-weed, but to be made up of the closely interwoven burrows of marine worms.

The Crustacea, with rare exceptions, are trilobites. They are exceedingly abundant, forming in some beds, and specially in the Wenlock limestone, the most conspicuous fossils. Many forms have been already quoted in the preceding chapters; and two woodcuts are here given, to represent either the principal forms not illustrated in the original work, or those now more perfectly known. Among the latter we may reckon

FOSSILS (63). UPPER SILURIAN CRUSTACEA.



1. Lichas Anglicus, Beyrich, and its hypostome or labrum. 2. Calymene tuberculosa, Salter, also with its labrum. 3. Lichas Barrandii, Fletcher. 4. Beyrichia Kloedeni, M'Coy; natural size and magnified. The other figures are reduced to about half size.

the elegant and highly ornamented Dudley fossils, Encrinurus punctatus, Foss. 64. f. 5, and E. variolaris, f. 6. These, which are known by the name 'strawberry-headed' by collectors, are found on every slab of Wenlock limestone, but seldom perfect except at Dudley, where numerous specimens ornament the cabinets of Mr. Gray and Mr. Fletcher of that place. Cheirurus bimucronatus, Foss. 64. f. 4, figured from fragments only in my old work, is found perfect in the same collections, and in the cabinet of my friend the Rev. T. T. Lewis. The singular genus Acidaspis (mihi) is now better understood than when formerly described, and no less than six species of this genus, besides Acidaspis Brightii, Sil. Syst. (Pl. 18. f. 7, and Foss. 64. f. 8), are known in the Upper Silurian rocks. The head, Foss. 64. f. 9, of one of the largest species, called

* Mem. Geol. Surv. vol. ii. part 1. pl. 4.

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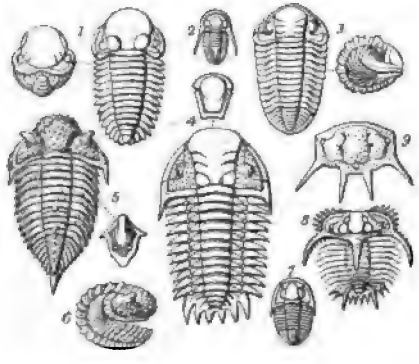
A. Barrandii by Mr. Fletcher, is here figured. It belongs to a group remarkable for having the lobes of the head nearly obliterated, and possessing two large neck-spines. The common Calymene Blumenbachii, Pl. 18. f. 10, is, perhaps, the most prolific of all the Silurian trilobites, and is besides, as before stated, known in the lower division of the system. C. tuberculosa, Pl. 18. f. 11, and Foss. 63. f. 2, which was formerly given as a variety of it, is a very plentiful species in the Wenlock shale.

Among the trilobites here figured which were not published in my former work, Sphærexochus mirus, Foss. 64. f. 1, is singularly formed; the head being so inflated as to resemble a ball. This Wenlock fossil has a very general geographical or horizontal range, being found both in America and Bohemia in Upper Silurian rocks. It appears, however, to have existed earlier in Britain than in those distant parts; for it is found in the equivalent of the Caradoc rocks in Ireland. Four or five species of Lichas (a genus already figured in Chap. 9) are now known in Wenlock limestone. The genus is remarkable for the shape of the head and its lobes. L. Grayii, L. Salteri, L. Barrandii, Foss. 63. f. 3, and L. hirsutus, are all species figured from the rich collection of Mr. Fletcher (Quart. Geol. Journ. vol. vi. p. 235). With them is associated

FOSSILS (64). WENLOCK LIMESTONE TRILOBITES.



1. Sphærexochus mirus, Beyrich, with a coiled-up specimen. 2. Cyphaspis megalops, M'Coy. 3. Phacops Downingiæ, both extended and coiled-up. 4. Cheirurus bimucronatus, and its labrum or lip. 5. Encrinurus punctatus, and its labrum, drawn from a Dudley specimen. 6. E. variolaris. 7. Proetus latifrons, M'Coy. 8. Acidaspis Brightii, in part restored. 9. A. Barrandii, Fletcher & Salter, the head.

a small and very common species, the L. (Arges) Anglicus of Beyrich, Foss. 63. f. 1, of which a very imperfect illustration was formerly given in Brongniart's work, from a Dudley specimen. It occurs also in Upper Ludlow rock, in the Whitcliffe, Ludlow. Phacops Downingiæ, Foss. 64. f. 3, and Pl. 18. f. 2–5, P. caudatus, Pl. 18. f. 1, with its variety, P. longicaudatus, Pl. 17. f. 3–6, have been already quoted (p. 134) as very common forms.

Proetus Stokesii, Pl. 17. f. 7, and P. latifrons, Foss. 64. f. 7, are also far from rare in Wenlock strata. The Bumastus Barriensis (Illænus, auct.), Foss. 16, p. 123, and Pl. 17. f. 9–11, ranges, as before said, from

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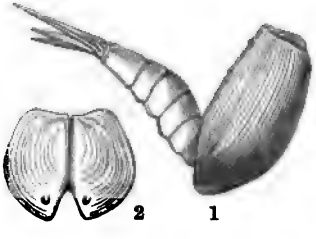
the lowest Wenlock beds to near the top of the Upper Silurian. This fine fossil occurs of the largest size in the Woolhope limestone, and is found in the pipeclay beds of that formation at Malvern. Two species of Homalonotus also have been already quoted, pp. 123, 147; the H. Knightii being very characteristic of the Upper Ludlow rock.

Cyphaspis megalops, Foss. 64. f. 2, and a small species, C. pygmæus, Salter, are the only species of that genus known in England. The former began life in the Lower Silurian epoch. Deiphon Forbesii, Barrande, is a rare, globular-headed trilobite, found both in the Dudley limestone, and its equivalent rock in Bohemia. And lastly, there is a species of Bronteus, probably the B. laticauda, Wahlenberg, found by my deceased friend Dr. Lloyd, in the Wenlock limestone. It is figured by Professor Phillips under the name of B. signatus (Palæoz. Foss. of Cornwall, &c., f. 254). The original of this rare fossil is in the cabinet of Mr. Tennant, of London.

A goodly list of trilobites of the Upper Silurian rocks has thus been given, and many other forms will probably reward research.

The small bivalve crustaceans, called by M'Coy Beyrichia, remain to be noticed. Of this genus, the Upper Silurian species is B. Klœdeni, M'Coy, according to Mr. T. Rupert Jones, our best authority on these subjects, Foss. 63. f. 4. It is a very abundant species from the base of the Wenlock shale to the highest Ludlow stratum, varies greatly in shape, and is a good index of the Upper Silurian, though found sometimes in the Llandovery rocks; whilst B. siliqua, Jones, has lately been detected in slabs of Woolhope shale near Malvern. The Lower Silurian form, it will be recollected, is B. complicata, Chap. 9. p. 223. These bivalve crustacea are numerous and of a finer growth in the Upper Silurian limestones of Sweden; and, together with the still larger Leperditia of Gothland, are, in the opinion of good naturalists, probably of the Phyllopod tribe, and more nearly allied to living forms than the trilobites that accompany them.

FOSSILS (65). AN UPPER SILURIAN CRUSTACEAN.



Ceratiocaris from Lesmahago, f. 1, with its abdomen recurved; and f. 2, the carapace of another species, showing the two valves of which it is composed.

So also may be some larger, shrimp-like forms, Ceratiocaris, from the Ludlow rocks of Kendal, Ludlow, and the S. of Scotland. One of these, the C. inornatus, is three or four inches long. The carapace, or front part

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only of the body of this species, was described by Professor M'Coy; but the possession of more perfect specimens of other species—some even of greater size—has now permitted the delineation of the entire form; and the present opportunity is seized to correct an error in a previous description*, in which the anterior was mistaken for the hinder end of the carapace. Prof. M'Coy, indeed, thought he had discovered the eye near the pointed end; and if such were the case, the analogy with the small schizopod crustacea (Cuma, Bodotria, &c.) would have been very considerable. But there is good evidence that Ceratiocaris was a bivalve crustacean, probably of the Phyllopod tribe, and that the truncated, not the pointed end, was anterior. To the same genus also belong those curious striated crustacean spines which are represented in Pl. 19. f. 1, 2. They have been minutely distinguished, by Prof. M'Coy, from fish-defences, with which they were formerly confounded. (See Chap. 7. p. 148.) That naturalist, indeed, supposed them to be the slender pincers of some large crustacean from the Lower Ludlow, and hence called them Leptocheles, viz. L. leptodactylus, M'Coy, and L. Murchisoni, Pl. 19. f. 1. But M. Barrande had, at the same time, found more perfect specimens in Bohemia, indicating that these long pointed spines are the trifid tail of a crustacean, something like that of the carboniferous genus Dithyrocaris. His accurate figures, as yet unpublished, show, however, only the terminal segment of the abdomen. The perfect specimens from Ludlow and Lesmahago show the entire structure; and we are now, therefore, able to unite all these forms in one genus. There cannot be less than twelve or fourteen species distributed in the Lower and Upper Ludlow rocks: some of them must have been nearly a foot in length, and others are minute.

The largest, if not the most highly organized crustacean in the Silurian list, is the Pterygotus problematicus, before mentioned. The fragments of the body-rings, which are represented, Pl. 19. f. 4, 5, were at first considered by Agassiz to be fish-scales†; but that author soon afterwards‡ corrected his statement, and assigned the animal its true place among the Crustacea. Reference has already been made to several other species, pp. 140, 155, the most gigantic of which, perhaps, occurs in the Tilestone quarries of Kington. The dimensions which P. problematicus, the Ludlow species, attained are unknown; though, from fragments of the pincers described by Strickland and Salter§, it was probably not much less than that of the great fossil, the 'Seraphim' of the Scottish quarrymen, which must have been 6 or 7 feet in length||. Prof. M'Coy has referred these monsters of their order to the group of the

* See Salter; Quart. Geol. Journ. vol. xii. p. 33.

† Sil. Syst. p. 606.

‡ Poiss. Vieux Grès Rouge, pl. 1.

§ Quart. Geol. Journ. (1852) vol. viii. p. 386. pl. 21.

|| The P. (Himantopterus) Banksii could not have measured as many inches.

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Xiphosura, of which the large king-crab is the modern type; and Ferd. Roemer has beautifully figured an allied and complete form, the Eurypterus of DeKay, from the neighbourhood of Lake Erie, which he considers as belonging to the same group*. Eichwald's figures of the Russian Eurypteri (see p. 179) are also very good, and now that the entire form of Pterygotus itself has been discovered, they help to complete the evidence for the formation of a new family of Crustacea. These are the Eurypteridæ—already so named by Burmeister, but with a different meaning to that which the term now implies.

In a memoir already quoted (Quart. Journ. Geol. Soc. vol. xii. p. 28), Professor Huxley has given reasons for considering these great crustacea to be of a type nearly resembling some of the smallest of our living decapod crustacea (Alauna, Bodotria, Cuma,&c.), and as even showing great similarity to the larval state of the higher forms; and he adopts the term Eurypteridæ as including these two genera of paleozoic age, if not some others, at present unsatisfactorily arranged among the Phyllopods.

The restoration of these huge Pterygoti can now be effected, and an attempt has already been made (p. 155) to show the entire form of the P. Anglicus.

In this restoration the mandibles, with their palpi, are seen in their true place, and in the figures given at p. 178, Foss. 25, fig. 4 shows the serrate tips to the great foliaceous bases of the swimming-feet (fig. 3). These two portions, figs. 3, 4, should, indeed, be united in a single figure; but the usual appearance is that given in the figure, the swimming-feet being rarely found perfect.

The entire form was very simple: a small, half-oval, or subquadrate carapace, followed by twelve convex body-rings—the last of which formed a pointed, truncate, or even bilobed tail-joint; two large, compound eyes on the sides of the carapace; and beneath it a wide epistome, divided into three lobes, of which the central one is long, narrow, and expanded at the tip.

Four pairs of appendages only are known,—a pair of large 4-jointed antennæ with massive chelæ, which are furnished with sharp cutting teeth, large and small; a pair of mandibles with serrate edges, and with a single palpus of 5 or 6 joints. Then there is the large pair of swimming-feet of seven joints each, the basal one excessively large and serrate at its inner edge, and the terminal ones expanded for swimming, like those of the pelagic crabs (Portunus, &c.).

These are all attached to the carapace. No appendages to the rings of the body have been observed—indeed, it is clear that none existed,—a circumstance which Prof. Huxley regards as of much importance in determining the affinities of these old crustacea.

* Dunker and Meyer, Palæontographica, vol. iv. pt. 1. p. 8. pl. 2.

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Eurypterus, though resembling Pterygotus, differs from it in having the eyes on the middle of the shield*—not lateral; also by the want of the great pincer-like claws, as we find by the figures given in various authors. Three or four species of the genus have been found in Britain, and they have the same scale-like sculpturing, though less conspicuous than in Pterygotus.

The distribution of these two genera is as follows:—

As already stated, p. 106, there is a rare species of Pterygotus in the Llandovery rocks, though it is only of late that any forms of the genus have been found in so old a rock even as the Lower Ludlow. Two species occur in the last-named stratum: the chief one, distinguished by its prominent and pointed squamæ, and by its long swimming-feet, has been called P. punctatus; its mandibles are furnished with great fringed palpi. The other species has more open sculpture, like that of the P. problematicus, which is characteristic of the *Upper* Ludlow rock. Of this latter species, mere fragments are yet known, including parts of the feet, the jaws, the antennæ (described as pincers, see p. 263), and some portions of the under side. There are, however, at least two large and several small species in the Upper Ludlow rock.

Again, from the tilestones of Kington, Herefordshire, Mr. Banks has disinterred another fine Pterygotus, which has a wide expanded precaudal joint and a head rounded in front. This is not the same species as the large fossil already described under the name P. Anglicus, which has a blunt and truncated head: and, as it appears not to be identical with the fragments of P. problematicus of Agassiz, it will be named P. gigas. This must have been truly a gigantic fossil, rivalling, if not exceeding in size, the nearly allied P. Anglicus, which has already been figured in Chap. 7.

As tending to indicate an exact horizon for some of these species, it may be remarked that the P. gigas is now known to occur just at the junction of the Silurian and Old Red formations both at Kington, at Ludlow, and near Kidderminster. There is reason to believe that the beds in Forfarshire, in which the great Pterygotus Anglicus, its closest ally, is found, are of the same date.

Both in Scotland and in Worcestershire the Pterygotus is accompanied by the Parka decipiens (see Chap. 11), a fossil which Dr. J. Fleming supposed to be the fruit (or receptacle of the fruit) of some plant. There is strong reason for thinking that these fossils are, on the contrary, the *egg-packets* of Pterygotus. They were of a discoid shape,

* Pterygotus was formerly supposed to have the eyes in this position (Lyell's Manual, 5th edit., p. 420). Now that the true lateral place of these organs is known, Himantopterus will only form a subgenus with elongate eyes, and some differences in the under parts of the head: for instance, the central lobe of the epistome is ovate instead of sagittate, the palpi longer, &c.

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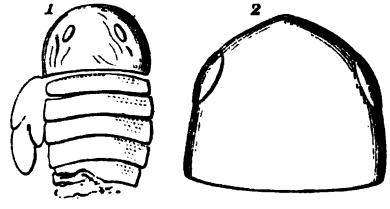
attached by a long pedicle, and are puckered and plaited from the point of attachment as from a centre. The appearance is as if a tough membrane containing rounded and rather soft egg-shaped bodies had suffered compression in the rock. The ovoid masses afford no indications of a style or stigma, such as must have been present had they been of the nature that Dr. Fleming supposed. That a great crustacean, so like in many respects to the Copepoda, should have had large pedunculate ovisacs, is far from unlikely, although the discoid shape of the fossil bodies* is different from that of the living forms.

There are indications of several other species of Pterygotus in the tilestones: P. Banksii, the least of them all, is figured here, Foss. 66. f. 2.

FOSSILS (66).

PTERYGOTUS AND EURYPTERUS, FROM THE TILESTONES OF KINGTON.



1. Eurypterus pygmæus, Salter.

2. Pterygotus Banksii, Salter.

As far as has yet been ascertained, the genus Eurypterus did not begin to live so early as the Pterygotus, the oldest yet found being the E. Cephalaspis†, Salter, from the Upper Ludlow rocks of Westmoreland; but it seems to have continued longer in existence. The E. pygmæus, Salter, Foss. 66. f. 1, a small and abundant species in the tilestones at Kington and Ludlow, and other species occurring at the latter place, are yet undescribed. The genus occurs in beds of the same age in Russia, as already noted (p. 179). And, as we shall afterwards see, a fine species (or two) is found in the Old Red Sandstone, and also in the lower beds of the carboniferous rocks of Scotland, from whence they were first described by Dr. Hibbert‡.

In the former edition it was affirmed, that in the true bone-bed of Ludlow no remains of fish, save those of a few placoid genera, were to be met with. Even here their remains are very scanty, some of those few which were formerly referred to the class having been removed, as stated at p. 148, to crustaceans. But those remarkable heads called

* Dr. Mantell suggested that these were ova of Batrachians (Quart. Geol. Journ. vol. viii. p. 106; see also Lyell's Manual, 5th edit., p. 421); but Mr. D. Page has remarked, that not only are some of them probably of vegetable origin, as described by Dr. Fleming, but others are possibly the spawn of batrachians and molluscs, and even of the crustaceans so common in the Old Red (Advanced Textbook, 1856, p. 127).

† Appendix to Pal. Foss. Woodw. Mus. pl. I *E*. fig. 21.

‡ Trans. Roy. Soc. Edinb., 1st ser., vol. xiii. pl. 12.

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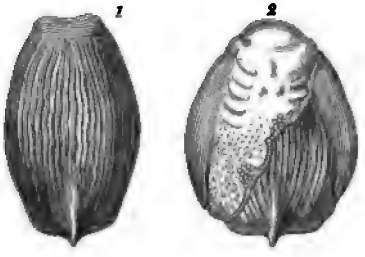
Pteraspis (Pl. 37. f. 9–11) are still to be referred to fishes, according to the recent observations of Prof. Huxley, who has ascertained that there is no essential difference between their structure and that of Cephalaspis. There are at least two species of these old anomalous Ganoid? fishes in the Ludlow rock itself. Both have been found near Ludlow—one in the grey Ludlow rock, by Mr. John Harley, of King's College, London; the other, by Mr. A. Marston, in the Bone-bed of Ludlow.

The first of these, which is of a plain oval form, and with only fine longitudinal striæ, is probably the P. truncatus, Huxley and Salter, Foss. 67. f. 1; the other, a broader species, is the P. Banksii, id., f. 2. Both of these (here figured) were discovered by Mr. Banks in the "passage-beds" of Kington in Herefordshire (p. 153); the latter species has been also found near Kidderminster by Mr. Geo. Roberts of that place, together with the Pterygotus before mentioned. The two species of Cephalaspis in the shale at the Ludlow Railway Station (p. 156) must not be forgotten. The occurrence in true Ludlow strata of one, if not two, species of true fishes identical with those of the transition-beds is a fact of importance, as tending to connect the latter intimately with the Silurian rocks.

FOSSILS (67).

FISHES (PTERASPIS) FROM THE LUDLOW ROCK AND TRANSITION BEDS.



1. Pteraspis truncatus, Huxley and Salter, from the "Passage-beds," Kington. 2. P. Banksii, id.; an ornamented species, showing, too, the cervical spine. From Upper Ludlow rock at Ludlow: the same species occurs in the "Passage-beds."

But besides these, and in the Ludlow bone-bed itself, there are true remains of other fishes*,—defences of the fins of shark-like species, with shagreen or skin, jaws and teeth, and other minute fragments less easily determinable.

Onchus tenuistriatus, Pl. 35. f. 15–17, and O. Murchisoni, f. 13, 14,

* In a survey of the May Hill district, in Gloucestershire, made whilst the pages of the first edition were passing through the press, Mr. H. E. Strickland and myself, re-examining the cutting of the Gloucester and Ross railroad, near Flaxley (which my friend had already described, Quart. Journ. Geol. Soc. vol. ix. p. 8), discovered two thin bone-beds, each little more than an inch thick, and separated by about fifteen feet of fossiliferous Upper Ludlow rock. On the same occasion we observed, that the only remains of small land plants (one of which seemed to be a stem, and the others numerous seeds, termed 'spore-cases of Lycopodiaceæ' by Dr. Hooker) occurred in beds above the uppermost fish-layer, *and therefore at the very top of the Ludlow formation, just beneath the lowest beds of the Old Red*, in which we found a Cephalaspis; the two deposits being there conformably juxtaposed. See Chap. 7.

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are bony fin-defences, such as are possessed by placoid fishes of the present day. Sphagodus, f. 1, 2, is the prickly skin of some such animal, and may have belonged (as suggested by M'Coy) to one of the former. The small cushion-like bodies, f. 18, called Thelodus parvidens by Agassiz, that occur by myriads in the stratum, often forming large portions of its thin layers, are certainly the granules of the skin, or shagreen, of one or other of these two common species. The remarkable jaws and teeth, Pl. 35. f. 3–8, first figured in my former work, and named by Agassiz Plectrodus mirabilis and P. (Sclerodus) pustuliferus (f. 9), must still be regarded as the jaws and anchylosed teeth of some small Ganoid fish; possibly even (as suggested by Mr. Salter) of Pteraspis or Cephalaspis: the teeth of these genera, if they had any, being yet unknown. Prof. M'Coy, however, is inclined to refer these bodies also to the order of Crustaceans, an opinion which, from the descriptions of Egerton, is not tenable. Their texture is solid and bony, and retains the jet-like lustre which the other fragments exhibit.

Again, as evidence of the predaceous habits of some of these fish, there are the small coprolitic bodies (Pl. 35. f. 21–28), which, according to Dr. Prout's analysis, contain the due admixture* of phosphate and carbonate of lime, with other matters; they retain also, imbedded in them, fragments of the various small mollusca and crinoids which inhabited the sea-bottom in company with the fish. It thus appears, that Bellerophon, Holopella, Lingula, Orbicula, and Orthis were all preyed upon by these minute but dominant creatures; and the half-digested shells remain here, as in the excrement of fishes of many later formations, and of the present period, to attest the character of their food and the extent of their depredations.

Twenty years have now elapsed since I announced that these fishes of the Upper Ludlow rock appeared before geologists as *the most ancient beings of their class*†; and indefatigable subsequent researches in the various parts of the world over which Silurian rocks extend have as yet failed to alter this generalization. In other countries, indeed, besides our own, as in America and Bohemia, and notably of late in Russia‡, ichthyolites have been discovered within the pale of the Silurian rocks; but there, as with us, they are merely found on the outer threshold of the system, and, except in Russia, very sparingly. We may, therefore, fairly regard the Silurian system, on the whole, and certainly all the Lower

* Sil. Syst. pp. 199, 607.

† Sil. Syst. c. 45. p. 606.

‡ The enigmatic, microscopic fossils named Conodonts by Pander, and which occur in the Lower Silurian rocks of Russia, I do not class as fishes. The affinities of these little bodies will be explained in the Appendix.

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Silurian, as representing a long, early period, in which no bony vertebrated animals had been called into existence.

But here we must recollect that, when first created, the Onchus of the uppermost Silurian rock was a marine fish of the highest and most composite order; and that it exhibits no symptom whatever of transition from a lower to a higher grade of the family, any more than the crustaceans, cephalopods, and other shells of the lowest fossiliferous rocks, all of which offer the same proofs of elaborate organization. Nor does the structure of Pteraspis, which must now be regarded as the earliest known British genus, since it occurs *below* the Ludlow bone-bed, offer, in Professor Huxley's opinion, any evidence of having occupied a lower position in the scale than existing Ganoid or possibly Siluroid fishes. In short, the first created fish, like the first forms of those other orders, was just as marvellously constructed as the last which made its appearance, or is now living in our seas.

In a word, the geologist who stands on the summit of the Silurian rocks of Shropshire and Herefordshire, where they graduate imperceptibly into the Old Red Sandstone, and casts his eye westward over the mountains of Wales, sees before him ancient masses in which, though replete with copious animal remains—the tenants of pre-existing shores and deep sea-bottoms, no traces of Vertebrata have ever been detected. In looking eastward, on the contrary, hills of red sandstone appear, the lower strata of which immediately succeed to the fish-beds of the Ludlow rocks, and in those he finds that fishes are the characteristic fossils.

Examining upwards from that first great *piscina* of by-gone days, the Old Red Sandstone or Devonian, which will be considered in the next chapter, he ascertains that all the superjacent and younger strata, whether primary, secondary, or tertiary, are more or less characterized by containing ichthyolites. In other words, the two or three peculiar fishes just enumerated may be viewed as the heralds which announced the close of the Silurian era in Britain, and the advent of the numerous other families of this class, which thenceforward are found in all the younger sediments. The name Silurian marks, therefore, the first series of fossiliferous deposits, throughout the great mass of which, no remains of vertebrated bony animals have been discovered.

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CHAPTER XI.

THE OLD RED SANDSTONE, OR DEVONIAN ROCKS, AS EXHIBITED IN THE BRITISH ISLES.

HAVING described at some length the lowest known receptacles of former beings, a shorter consideration only can be devoted to the younger races which were successively enclosed in the higher tiers of the vast primeval burying-places.

During the accumulation of nearly all the Silurian deposits of Britain, which were characterized by a certain fauna, the bottom of the sea was, to a wide extent, occupied by dark and grey-coloured sediments. At the close of that period a great change occurred over large areas in the nature and colour of the submarine detritus. In and around the Silurian region, for example, the dark grey mud was succeeded by red silt and sand; the colour being chiefly caused by the diffusion of iron oxides in the waters*. These physical changes were accompanied by the disappearance of those tenants of the deep, the records of which we have been tracing, and by the appearance of other animals.

The gradual passage upwards from the highest strata of the grey Silurian rocks into such red deposits of England, Wales, and a part of Scotland, has already been alluded to†, and illustrated by several diagrams.

In the lower junction beds, as seen within the Silurian region, it is only by the detection of certain Upper Ludlow fossils in thin beds or tilestones, partially also of reddish colours, that the limit can be defined, so gradual is the mineral transition from the strata of the one era into those of the other. Still the change is, on the whole, lithologically well-marked in that region, from the underlying grey Silurians to the overlying red and yellow rocks.

Good examples of this succession are to be seen near Ludlow, and between that town and the Clee Hills, and thence all along the eastern edge of the Upper Silurian rocks in Hereford, Radnor, and Brecon, as well as on the west flank of the Malvern and May Hills, and around the

* See some excellent observations on the influence of iron oxides on marine life, by the late Sir H. De la Beche, Mem. Geol. Surv. of Great Britain and Ireland, vol. i. p. 51.

† Pp. 57, 58, 61, 69, 96, 117, 121, 128, & 149–159.

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valley of Woolhope. But the grandest exhibitions of the Old Red Sandstone in England and Wales appear in the escarpments of the Black Mountain of Herefordshire, and in those of the loftiest mountains of South Wales, the Fans of Brecon and Carmarthen; the one 2860, the other 2590 feet above the sea. (See Map.)

In no other tract of the world, visited by me, have I seen such a mass of red rocks (estimated at a thickness of not less than 10,000 feet) so clearly intercalated between the Silurian and the Carboniferous strata. For, whilst (as represented in the higher of the diagrams, p. 272) the fore and middle grounds are occupied by Lower and Upper Silurian rocks, described in Chapters 3 to 7, the lofty, distant mountains are entirely composed of Old Red Sandstone. The observer has only to repair to the southern slopes of those mountains beyond the line of vision in the sketch, and he will there see the uppermost beds of the red rocks conformably overlaid by the carboniferous limestone of the Great South Welsh coal basin. (See lower diagram.)

If, then, the upper or pictorial sketch, which is repeated from p. 61, represents the whole region from the Lower Silurian slates to the summit of the Old Red, the sectional diagram, taken from one of the coloured sections of the 'Silurian System,' indicates the copious succession of red strata, which are exposed between the Upper Silurian, *a*, of the Trewerne Hills, and the carboniferous rocks, *g*, *h*, *i*, of the Great South Welsh coalfield near Abergavenny.

Consisting in its lower parts of red and green shale and flagstone, *b*, with some small cornstones and whitish sandstone, *c*, the central and largest portion of the deposit is composed of spotted green and red clays and marls, *d*, which afford, on decomposition, the soil of the richest tracts of the counties of Brecknock, Monmouth, Hereford, a large portion of Salop (Shropshire), and small parts of Gloucester and Worcester. These argillaceous beds alternate, indeed, with sandstones, occasionally of great thickness. They also contain the greatest quantity of those irregular courses of mottled red and green earthy limestones, termed 'Cornstone,' and which, though usually consisting of small concretionary lumps only, expand here and there into large subcrystalline masses, particularly on the western face of the Brown Clee Hills, Shropshire. A higher member of the series is composed of grey, red, chocolate, and yellow-coloured, fine-grained, micaceous sandstones and flagstones, *e*, which, in certain tracts, are surmounted by pebbly beds and conglomerates, *f*, as along the encircling, underlying edge of the Great South Welsh coal basin. These last-mentioned rocks are as well exposed in the lofty escarpments of the Fans of Carmarthen and Brecon above alluded to, as in the range of hills near Abergavenny on the south bank of the river Usk. Similar hard sandstones and conglomerates constitute, in like manner, a symmetrical girdle around the coal basin of the Forest of Dean, Gloucester-

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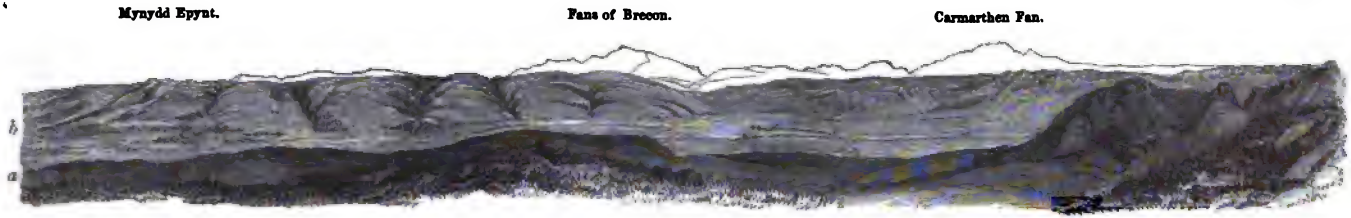

VIEW FROM THE SLATY LOWER SILURIAN ROCKS, *a*, NEAR LLANWRTYD, BRECON, OVERLOOKING ROUNDED HILLS, *b*, OF UPPER SILURIAN, WITH MOUNTAINS OF OLD RED SANDSTONE IN THE DISTANCE, THE LATTER BEING DEFINED BY THE UNTINTED OUTLINE.

(From a coloured drawing by Mrs. Traherne, Sil. Syst. p. 346.)

SECTION FROM THE TOP OF THE SILURIAN ROCKS, ON THE N.W., ACROSS THE WHOLE AREA OF THE OLD RED SANDSTONE, TO THE BOTTOM BEDS OF THE S. WELSH COAL FIELD, ON THE S.E. (Horizontal distance, 25 miles. From Sil. Syst. pl. 31. f. 1.)

N.W. S.E.

a. Upper Ludlow rock and Tilestones. *b*. Red marls and flagstones. *c*. Whitish sandstones. *d*. Red and green marls, sandstones, and cornstones. *e*. Chocolate-coloured sandstones. *f*. Conglomerate and sandstone forming the summit of the Old Red (in other parts a yellow sandstone). *g*. Lower limestone shale. *h*. Carboniferous limestone. *i*. Millstone grit. [To save space, the wide and deep valley of the Usk, between the Black Mountain and the lip of the S. Welsh coal-field, is omitted.]

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shire (see Map), where, and in the gorges of the Wye, as well as in the adjacent and much larger basin of South Wales, they are everywhere conformably overlaid by the shale and limestone which in these tracts, at least, compose the base of the carboniferous rocks. Occasionally, as under the carboniferous escarpments of the Clee Hills, Salop, these upper beds are of yellow colours. In short, the above generalized section gives an idea of the prevalent distribution of the strata within, and wrapping round, the original Siluria.

Now, whilst in all that region the only organic remains which have been found in this great red and green series, with the single exception of the crustacean figured on the next page, are fragments of fossil fishes and a few plants, we shall presently see, that, with mineral conditions to a great extent similar, the widely spread Old Red Sandstone of Scotland, which is of equivalent age, has also yielded scarcely any other organic remains. This prevalence of fishes is in striking contrast to all that has been said of the great mass of the contiguous and underlying Silurian rocks of Britain, in which no trace of a vertebrated creature has been found, except in those higher beds which usher in the natural group under consideration.

In Herefordshire and Brecknockshire, as well as in Shropshire, remains of ichthyolites were formerly described as occurring chiefly in strata where calcareous matter is most diffused; fragments and scales of fishes having been often detected in the cornstones, though the best specimens have been procured in the finely laminated flagstones and marls which are in the vicinity of those concretions. The fishes of this region, none of which were known to geologists before the publication of my larger work, belong to the genera named by Agassiz—Cephalaspis, Onchus, and Ptychacanthus; and figures of them, as taken from the 'Silurian System,' are repeated in Plates 36 & 37 of this work. To these the Pteraspis, formerly supposed to be a Cephalaspis (P. Lloydii and P. rostratus), figured in the 'Silurian System,' have since been added. Others will be noticed in describing the Scottish Old Red.

The lowest Old Red strata in which I had personally observed the remains of the peculiar fish Cephalaspis, when the first edition of this work appeared, are at the western slope of the Silurian ridge of May Hill*. In examining the cuttings of the Ross railroad, near Flaxley, my lamented friend, Mr. H. E. Strickland†, and myself detected a fragment of that ichthyolite in the very bottom beds of the Old Red, which,

* See Sil. Syst. pl. 36. f. 13.

† The passage of the first edition of my work through the press having been delayed until I returned from a tour in Germany, I learned with profound grief, upon my arrival, of the lamentable catastrophe by which, in examining another railroad cutting, my eminent friend, Mr. H. E. Strickland, had been taken away from those sciences of which he was so great an ornament. The correction of some of these pages by his hand, during my absence, was one of the last memorials of a friendship which I truly cherished.

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containing also certain land plants, there lie in apparent conformity upon the uppermost Ludlow rocks.

More recently, indeed, the sections near Ludlow, particularly on the right bank of the Teme, have afforded those fresh evidences of a transition from the Upper Ludlow into the Lower Old Red which have previously been adverted to (p. 154), and which render it difficult to draw any arbitrary line (within a few yards at least) for the horizon which may separate the two formations. In Shropshire, we find, in ascending from the Tilestones into the marls and sandstones with concretions of argillaceous limestone (and the same phenomenon re-occurs near Kington in Herefordshire), that other species of Pteraspis occur, as well as other species of Cephalaspis, and particularly the C. Lyellii, and thus we are conducted at once into the great formation which, in parts of Scotland, also contains the same species.

In the red ground two miles north of Bewdley, near Trimpley, in Worcestershire, greyish-coloured sandy grits and cornstones rise out in undulations,—the cornstones charged with the Cephalaspis Lyellii, Pteraspis Lloydii, and the underlying grits with P. Banksii, Pterygotus gigas, and eggs of this crustacean? (Parka decipiens), &c., with many remains of plants, including the small Lycopodiaceous sporangia.

An important addition has recently been made to the fauna of the Old Red Sandstone of England by the discovery of a Eurypterus at Rowlestone in Herefordshire, in the lowest portion of those sandstones

FOSSILS (68). CRUSTACEAN FROM THE OLD RED OF HEREFORDSHIRE.

Eurypterus Symondsii, Salter; from Rowlestone, S. of the Hay, Herefordshire.

The cephalic shield of a crustacean allied to Pterygotus. The species is remarkable for its deep sculpturing.

of the Black Mountain, near Hay, which overlie the cornstones, *d*, of the previous general section. This unique fossil, Foss. 68, was first brought into notice by my accomplished friend the Rev. W. S. Symonds*, the specimen having been found by the Rev. W. Wenman. In the higher portion of this series, near Crickhowell, I formerly found the scale of a large fish (Sil. Syst. p. 172), since ascertained to belong to Holoptychius.

Lastly, and even whilst I write, a new species of the remarkable genus Pterichthys, Ag., so characteristic of the Old Red of Scotland, has been discovered at Farlow, in Shropshire, in a yellow-coloured sandstone, which there occupies the highest portion of the formation,

* See Edin. New Phil. Journ., new ser., vol. vi. Oct. 1857.

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rising out from beneath the shale of the carboniferous limestone of the Titterstone Clee Hill, and graduating down into the mass of the red sandstone and subjacent cornstones. This species will be described by Sir Philip Egerton; and in the meantime it is well to remark, that whilst one form of the genus, which was first detected by Hugh Miller, lies in one of the lower beds of Cromarty, another species occurs plentifully at Dura Den in Fifeshire, where it is also in a yellow sandstone which has always been classed as the upper member of the group.

When we follow this series of red beds from Shropshire and Herefordshire through Brecknockshire and Carmarthenshire into Pembrokeshire, considerable lithological changes are seen to occur. Though the prevailing colour in the last-mentioned county is still red (the 'red rab' of Pembroke), some portions of the rocks consist of dull green and brown flags or sandstones, and others of hard grey grits, which even resemble certain inferior Silurian deposits; whilst true cornstone or limestone is rare, as are the traces of fossil fishes. Yet, the strata in question, to whatever extent attenuated in some tracts or placed unconformably in others on the Silurian rocks, occupy the same geological horizon as in the tracts of England and Wales previously mentioned, and lie clearly between the Silurian and carboniferous rocks*. In fact, few better sections of the Old Red Sandstone of Britain, in relation to the rocks beneath and above it, can be offered than are exposed around the magnificent land-locked bay of Milford Haven. (See Map.)

We shall presently show the order of succession in rocks of the same age under a different and more slaty aspect on the south side of the Bristol Channel in Devonshire, and indicate that, with a considerable change in their composition and a great increase in calcareous matter, the strata there contain many mollusks and marine animals unknown in the Silurian region, and equally distinct from carboniferous species.

Let us, however, previously consider the nature of the Old Red Sandstone of Scotland, where, preserving much of the same mineral character as in the parts of England just mentioned, the group, as seen in the N.E. Highlands, is more grandly displayed than in any other part of northern Europe.

Old Red Sandstone of Scotland.—Dwindling away from its copious development in Brecon, Hereford, and Salop, the Old Red Sandstone of the North of England is, as before stated, little more than a single band of coarse conglomerate—a small skirting mass merely between the Silurian and carboniferous deposits of the Lake region of Cumberland. This single member of a series so copious elsewhere, there reposes on the truncated edges of the older slaty rocks.

* The yellowish sandstones which, in Pembrokeshire, form the summit of this group, may at least in part be classed as the base of the carboniferous rocks,—*i. e.* they are beds of transition in which lower carboniferous fossils have been detected.

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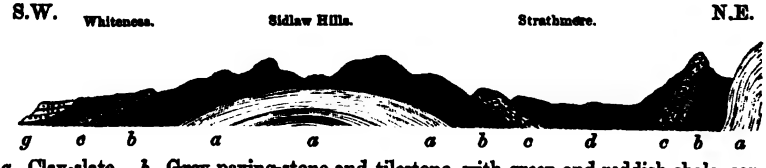
In the South of Scotland, where the Lower Silurian strata are so fully developed, the uppermost Silurian or Ludlow rocks have as yet been discovered in one tract only, and there the same conformity of succession is observed between the dark Silurian schists, *b*, and the overlying red shale, *c*, of the diagram in p. 177. But although the discovery in Lanarkshire seems to connect the Silurian series with the next superior formation, it is to be noted that the Lower Old Red Sandstone of that tract is comparatively of small dimensions, and has not yet afforded any characteristic organic remains. Again, whilst the formation in Lanarkshire lies between Upper Silurian rocks and the bottom of the carboniferous strata, and therefore is in true order of position, the ascending series towards the carboniferous rocks which are there so admirably exposed, is broken off, as seen in the diagram, p. 177. In other words, all the great masses of rock which constitute the central and superior members of the group in the N.E. of Scotland, are there omitted. Powerful masses of porphyry are protruded, and the upward sequence from the Old Red conglomerate is entirely omitted.

Indications of the presence of the uppermost member of the Silurian rocks also exist in Forfarshire, and particularly on the flanks of the Sidlaw Hills, where the grey paving-stones of Arbroath repose upon clay-slate, and contain the crustacean Pterygotus Anglicus, which appears to be identical with that of Shropshire* (see Chap. 10. p. 264). The following general section over a part of that region, as given by

SECTION ACROSS THE OLD RED OF FORFARSHIRE.



a. Clay-slate. *b*. Grey paving-stone and tilestone, with green and reddish shale, containing Pterygotus and Parka decipiens†. *c*. Red conglomerate. *d*. Red sandstone, with ichthyolites, &c. *g*. Red shale or marl, unconformable to the lower rocks.

Sir C. Lyell in his 'Manual of Geology,' is to me indicative that the clay-slate, *a*, which underlies the Old Red, may possibly also belong to the Upper Silurian rocks.

It is further to be inferred, that whether we group the grey paving-

* Quart. Journ. Geol. Soc. vol. vii. p. 169.

† My valued friend, the late Rev. John Fleming, D.D., who wrote original papers on the organic remains of the Old Red Sandstone, first assured me, that a fruit-like body found in Fifeshire and in the Arbroath paving-stones of Forfarshire, was unquestionably a vegetable, and could not be classed as the egg of a mollusk, as suggested by Lyell, or as the egg of a batrachian, as more recently proposed by Mantell. The figure which Dr. Fleming gave in the year 1831, Edin. Journal of Nat. Science, vol. iii. pl. 2. f. 5, certainly favoured the opinion that it was an aggregate fruit. Since then he examined both the upper and under surfaces, and quite satisfied himself that it is a receptacle, and that the round covering bodies are carpels or fruits. It is now known to be the Parka decipiens.

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stone of Arbroath, *b*, of the section, with the Ludlow rocks or with the Old Red, to which it has hitherto been attached, it clearly occupies the place of the Tilestones of the Silurian region, and contains, like them, large Pterygoti and the Parka decipiens. The Cephalaspis beds which immediately succeed will be spoken of in the sequel.

Typical Region of the Old Red Sandstone.—It has already been shown, that in one part of the South of Scotland the uppermost Silurian rock, with its fossils, is overlaid conformably by red shale and sandstone (p. 177)*. Such Upper Silurian basis is, however, wanting in the Northern Highlands, and the reason is obvious. We now know that rocks of Lower Silurian age, associated with, and reposing on, old conglomerates, have there been metamorphosed into a crystalline state, and that a great change of the crust took place in the former outline of land and sea, in consequence of which, as we have every reason to think, no Upper Silurian sediment was ever accumulated.

To eliminate, however, with precision the extent to which those crystalline Highland rocks, whether quartzose, gneissose, micaceous, or chloritic, with subordinate limestones, may represent various Silurian subformations, must still be a work of long labour. In the meantime it is clear, that, ranging south-west from Sutherlandshire into Rossshire, they constitute in Loch Alsh and Kintail that lofty and steep watershed so near to the west coast of the Highlands, the strata of which, dipping rapidly to the E.S.E., are, after numerous undulations, transgressively surmounted by the lower member of the Old Red Sandstone of the eastern counties (see long section, p. 199).

Wherever these two great systems of metamorphosed Lower Silurian rocks and the overlying Old Red Sandstone are in contact, the direction of the one is completely discordant to that of the other.

Thus, whether the older system be viewed in the western part of Sutherland and Ross, where limestones are intercalated in quartzites, or in the eastern tracts of those counties, where gneissose and micaceous schists prevail, the strike which is most frequent is seen to be from *N.N.E.* to *S.S.W.*, the dominant dip being to the E.S.E. The Old Red conglomerate of the east coast is, on the contrary, thrown off the promontories of the older system in devious directions, the prevailing dip in Caithness being to the N. of E., and even N.N.E., in the northern part of Ross-shire to the S.S.E., and on the south side of the Murray Frith again to the N.N.E. A complete unconformity is, in short, everywhere observable, independent of the fact, that the younger deposit is literally made up of the debris of whatever portion of the older on which it happens to rest. In this way we observe, that the conglomerate of one spot is chiefly made up of quartz rock; in another, of mica-schist; in a

* See also Quart. Journ. Geol. Soc. vol. vii. p. 168; vol. viii. p. 386.

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third, of gneiss; in a fourth, of granite; and occasionally of all these and other varieties of the older system mixed together.

Then, again, nothing can be more dissimilar than the physical outline of these two rock-systems. Whilst the quartzo-micaceous, crystalline rocks resemble in outward form a tumultuous sea, the observer who stands on the conglomerate which lies on their eastern edges sees beneath him, to the east, the highly contrasting outline of soft undulations, which in the low countries of Caithness, Easter Ross, Inverness, Nairn, and Elgin, die away gradually to the sea-board. So strong is this contrast, that the geographer unacquainted with geological science would at once say, that these two rock-systems belonged to very different epochs in the history of the earth's crust.

In no tract of Britain, indeed, is there so clear a succession of the whole group of the Old Red Sandstone, properly so called, as that which is exposed on the north-eastern shores of Scotland. This order is especially well seen, after the observer, who has made himself well acquainted with the copious lower conglomerates and sandstones which fringe the crystalline rocks of Elgin, Nairn, Inverness, and Ross-shire, passes through Sutherland into Caithness and the Orkney Islands. This last is the region selected thirty years ago by Professor Sedgwick and myself* as affording what we then conceived to be the clearest example of the extended features of that great group of the British series, with which we long afterwards compared, as *an equivalent in time*, the slaty rocks, schists, sandstones, and limestones of Devonshire. (See pp. 292, &c.) Having revisited the north-east coast of Scotland since the first edition of this work was published, and having been confirmed in my former views concerning the general physical succession of the masses, a brief sketch of the leading phenomena is now given. This *résumé* is the more called for, as geologists who have never examined this eastern region, and have been disposed to consider the Old Red Sandstone as a kind of local formation only, have been unwilling to consider it to be the full equivalent in time of the Devonian rocks of other countries.

The massive conglomerates and intercalated red sandstones of the north-east coast, which occupy a great thickness of strata in Easter Ross, Cromarty, the Black Isle, and adjacent parts of Inverness-shire, and which, flanking the Oolitic tracts of Dunrobin and Brora, range northwards into Sutherlandshire, are very distinct in mineral character and relations to the ancient conglomerates and grits of the west coast. Whilst the latter (Cambrian) underlie all those quartz rocks and limestones which are now known to be of Lower Silurian age, the great pebble and boulder beds of the east coast and its inland recesses never assume the subcrystalline character of some of the western masses. On the con-

* Trans. Geol. Soc. Lond., 2nd ser., vol. iii. p. 125, with map of the Highlands, sections, and some figures of the Caithness fishes.

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trary, they overlap all such rocks, and, often containing gigantic boulders, graduate into, and alternate with, masses of grit and sandstones as sectile and as well fitted for building purposes as many freestones in the British Isles. The red sandstone associated with the conglomerate assumes, indeed, at places so variegated a character, with green spots and stripes, or earthy concretions, that, in early days, German geologists, unacquainted with the exact relations of the deposit, and judging from mineral characters only, would have referred such rocks to the 'Bunter Sandstein.'

The reader who desires to become better acquainted with the different varieties of such conglomerates and sandstones may peruse the descriptions given of them by Jameson, Boué, and the earlier writers, as well as by M'Culloch, Sedgwick, and myself.

Among the various authors who have described them, the lamented Hugh Miller stands pre-eminent. Born upon the Old Red Sandstone of Cromarty*, he has shed a bright lustre over this deposit of his native tract, and has expounded with a surprising sagacity the wonderful organization of many of its fossil fishes, and thrown the clear light of zoology upon these old pages of geological history.

The term Old Red Sandstone having thus been rendered classical, the name may well be retained as a synonym for the great group, of intermediate age between the Silurian rocks beneath and the Carboniferous formation above it, which, in those countries where it assumes more slaty, calcareous, and schistose characters, is termed 'Devonian.'

Among the older crystalline rocks which, rolling over from the west, constitute the masses out of which the red sandstone and conglomerate of the east coast have been formed, mica-schists prevail in Easter Ross; whilst in proceeding northwards into Sutherland, particularly in the Scarabin Hills, quartz rocks predominate. Now, the quartzites of these mountains present just the same bedding, and alternate with schists as in the western parts of the country, where the Lower Silurian fossils have been discovered. Thus, in descending from the Scarabins towards the sea, we meet with a regular succession of crystalline or subcrystalline, light-coloured, thin-bedded quartz rocks with argillaceous wayboards, and presenting all the aspect of a sedimentary origin, which, rising at high angles to the summits, are followed on their eastern flanks by other siliceous courses, some micaceous, and of various colours from

* See Hugh Miller's remarkable work, 'The Old Red Sandstone,' in the dedication of which to myself, he alludes to our both being born upon the Old Red Sandstone. In physical geography, Cromarty, the birth-place of Miller, forms a part of the peninsula of Ross-shire known as the Mull-Buy, or the Black Isle, in which my paternal estate of Taradale is situated, and where, as in the adjoining property of Red Castle, varieties of the building-stone have been long quarried. Ross-shire now affords, indeed, so many quarries of building-stone, whether light or dark red, and sometimes ribboned or spotted, that in proceeding from Inverness to Sutherlandshire by Dingwall and Tain, the traveller has ample evidence of the varied nature of the rock.

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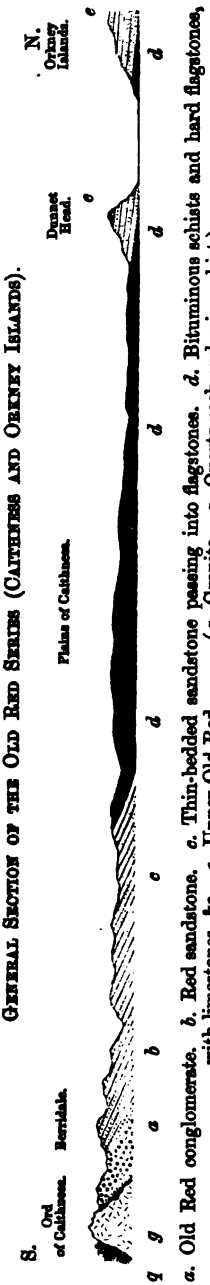

GENERAL SECTION OF THE OLD RED SERIES (CAITHNESS AND ORKNEY ISLANDS).

a. Old Red conglomerate. *b*. Red sandstone. *c*. Thin-bedded sandstone passing into flagstones. *d*. Bituminous schists and hard flagstones, with limestones, &c. *e*. Upper Old Red. (*g*. Granite. *q*. Quartz-rock and mica-schist.)

dull purple-brown to grey. At certain spots these quartzose rocks are broken up and penetrated by granite. It is upon the edges of these rocks, as ranging from the Ord of Caithness by the Scarabins to the Morvein Hill, that the base of the Old Red series of Caithness rests, the conglomerates composing the last-mentioned of these mountains occasionally rising along this fringe only, as Hugh Miller has well remarked, to higher altitudes than the older crystalline rocks.

Let us now consider the overlying series in a true ascending order by proceeding from the inferior red sandstones and conglomerates through the central masses of dark grey flagstones and schists to the higher sandstones which stand out in the northern headlands of Caithness and the Orkney Islands. The accompanying diagram indicates this succession in a general and compendious manner, the many detailed flexures and breaks in the strata being omitted.

It would be superfluous to describe the countless examples of splendid and massive conglomerates and sandstones, particularly those of Easter Ross, which, reposing on the crystalline rocks, are seen to constitute the base of this series. Remarkable exhibitions of such rocks may be seen in ascending the Orron and Connan rivers; and they range thence eastwards all along the southern flanks of Ben Wyvis and its associated mountains, and traversing the Kyles of Dornoch, extend through the eastern parts of Sutherland into Caithness.

Though in many of these localities, particularly in Ross-shire, these conglomerates are of vastly greater dimensions than in their extension into Caithness, there is no tract in which their relation to the overlying richly fossiliferous deposits is so well seen, and hence the section selected as a type is that which proceeds from the maritime promontory called the Ord of Caithness, where granite has been powerfully intruded among the older rocks. There, and in the recesses

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extending south-westward from Braemore along the edges of the quartz rocks of the Scarabin Hills, are exposed fine masses of conglomerate and sandstone dipping north-eastwards at a low angle. The same conglomerates form, in fact, the inland girdle of Caithness, rising up on the west from beneath the great flagstones of that low, undulating country, and separating those strata, so replete with fossil fishes, from the above-mentioned crystalline rocks.

Let the geologist proceed northwards from the edge of the crystalline rocks, and he will clearly see, first, that the lowest strata of conglomerate and red sandstone, as made up of the crystalline rocks, alternate with, and pass into, deep-coloured, thin-bedded red sandstones, as in the Old Man of the Ord, which constitute the natural and conformable base of the flagstone series of Caithness.

In order to convey to the reader some notion of the natural features of the lower portion only of this fine succession, a small sketch is annexed, as taken from the footpath on the northern side of the Ord, at a spot called Bad Bae.

VIEW OF THE OLD RED SUCCESSION, FROM NEAR THE ORD OF CAITHNESS.

The foreground is made up of the rude conglomerate, *a* of the opposite section, here chiefly composed of huge blocks of granite, the nearest rock, and of which the hut is built; though other smaller materials are of quartz rock and mica-schist. This bottom rock of the series is followed by deep red sandstones, which occupy the next headland known as the Man of the Ord, *b* of the diagram; whilst all these strata, inclining to the north, pass in their true order beneath the flagstones of Caithness, which occupy the distant low headlands (*c*, *d*, of the long section, p. 280).

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It would be a difficult task to endeavour to assign an average thickness to the accumulations of sandstone and conglomerate (the sandy beds being sometimes the lowest) that constitute the inferior member of this group; since it is in the very nature of pebbly accumulations which were formed either on coasts or in bays washed by the waves of a former sea to present the most variable dimensions. Independently of the conglomerates, and the occasionally interlaminated sandstones, often very finely laminated, these deposits must have occupied a long lapse of time in their accumulation.

The red sandstone of this lower zone, assuming gradually a flag-like character, and becoming of a purplish tint, passes up by other beds, *c*, into those grey-coloured flagstones which, forming the large portion of the county of Caithness, are so well known to geologists through their imbedded fossil remains, as described by Agassiz and Hugh Miller. From the environs of Lybster, where the strata (*d* of diagram) begin to contain fossil fishes, these flagstones present a general uniformity in their lithological characters; and, though here and there so calcareous as to have been in parts formerly burnt for lime, they are, on the whole, to be regarded as a great series of hard, argillo-siliceous beds of great tenacity, in which, since the days when I first described them (1826), large and valuable quarries have been opened out.

The real study of these flagstones from their lowest members near Dunbeath to their central parts at Wick, and thence to their highest strata on the shores of the Pentland Frith, where they pass up into, and are covered by, the red sandstones of Dunnet Head, is to be made in the precipitous coast cliffs, which, abraded by the surges of the ocean, exhibit many remarkable small bays and headlands, on the sides of which the hard flagstones present their rough and jagged edges*. The thickest beds, when quarried for building purposes, near Wick, are from 14 to 15 inches thick, and occasionally furnish blocks of 20 feet in length, which are of great tenacity and durability. In some of the calcareous courses Mr. C. Peach has recently discovered that the fragments of fossil fishes have in certain spots been ground down to a powder, which constitutes a large portion of the matrix of the rock.

Many of the beds are so bituminous, owing to the quantity of animal matter they contain, that even when described in 1827 they were termed by myself the bituminous schists of Caithness; bitumen being seen to exude naturally from them†. Having recently obtained specimens from near Barrogill Castle, as collected by Mr. Peach, I submitted them to

* Not having personally examined all the coast between Wick and Latheron Wheel, I requested Mr. C. Peach to do so, and he has detected the existence of an axis at Sarclet, by which conglomerates are again brought up, and are thrown off to the S. and to the N., thus passing on either side under the fish-bearing flagstones. These features are not represented in the general section, p. 280.

† See Trans. Geol. Soc. Lond., 2nd ser., vol. ii. p. 314.

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the analysis of Dr. Hofmann, who, according to the report given in the Appendix, attaches considerable value to this mineral if it be obtainable in sufficient masses. Now, as it has been found profitable to distil 'stone-oil,' or petroleum*, from beds of secondary age charged with fossil fishes, in high recesses of the Alps, we may certainly infer that these paleozoic strata lying so near the sea may yield so much bitumen, that, combined with the largely increasing demand for its valuable flagstones, the hard and arid coast of Caithness may become a well-peopled and industrial tract.

Besides fossil fishes, the Caithness flagstones contain numerous fossil plants, and both these classes of organic remains will presently be treated of†.

Continuing to trace the ascending order of the Old Red Sandstone series of Caithness into the Orkney Islands, it is to be noted, that the flagstones, usually of a dark grey colour, but here and there of purplish tint, graduate upwards into those higher light red sandstones and grits which, constituting the northernmost point of the mainland, Dunnet Head, are again seen in many parts of the Orkney and Shetland Islands, where they occupy a similar relative position. These upper sandstones (*e*, p. 280), into which there is a perfect transition from the harder flagstones, might in hand specimens be often mistaken for some of the beds which underlie the Caithness flags, both in colour and composition. In these sandstones land plants also prevail, particularly in the Shetland Isles; and according to Dr. Hooker they are referable to Calamites, generically resembling, but of species differing from, the forms known in the Carboniferous rocks‡.

Whilst the upper member of the group is clearly exhibited in Dunnet Head, Hoy Head, and many parts of the Orkney and Shetland Islands, it is also seen to the south as forming the headland of Tarbet Ness, north of Cromarty, and the Burg Head on the south side of the Murray Frith, where it is the matrix in which the oldest known reptile has been found, and of which a figure will presently be given.

Seeing that there is no sign in this northern region of a further passage upwards into any strata which can be classed as carboniferous, the triple subdivision of the Old Red Sandstone for which I have long

* See my paper on the Bituminous Schists of Seefeld; Proc. Geol. Soc. Lond. vol. i. p. 39.

† The most extensive quarries are situated a few miles east of Thurso, as opened out upon a very large scale by Mr. Traill, of Castle Hill. The flagstones are occasionally of gigantic dimensions, and often present casts of plants upon their surface.

‡ The plants in question were brought from Lerwick by the late Right Hon. H. Tufnell; and when, at his request, I presented them to the Geological Society, I confirmed my own views of their position, not only by reference to the work of Dr. Hibbert, but by consulting Dr. Traill and the Rev. Dr. J. Fleming, both of whom had visited Shetland, and were well acquainted with its rocks. The latter had observed plants many years ago in the sandstones of the Shetland Isles. (See Quart. Journ. Geol. Soc. Lond. vol. ix. p. 49; and further on, p. 292.)

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contended, is still adhered to. The equivalents of this great series will be afterwards noted in other parts of the world, where, with varying physical conditions, strata occupying the same place in the general series of deposits are found to contain the mollusca of Devonshire commingled with the ichthyolites of Scotland.

The same general succession as that of Caithness and the Orkneys is exhibited on a small scale between Cromarty and Tarbet Ness, and again in larger dimensions on the south side of the Murray Frith, along the seaward boundaries of the counties of Inverness, Nairn, Moray, and Elgin*.

The extent to which the variation of the lithological characters of the deposits in their range southwards has affected the distribution of the organic remains is explained in the sequel.

Animal Remains of the Old Red Sandstone.—When Agassiz completed his remarkable analysis and history of the fossil fishes of this deposit, the number of species enumerated from Britain alone amounted to sixty-five; and this number has since been augmented. Referring the student to that monograph, as well as to the fervid writings of Hugh Miller, let us now, in mentioning some of the principal types, endeavour to determine the order in which these ichthyolites appear geologically, or in the successive layers of this group of rocks.

It has been shown (p. 153 *et seq.*), that along the frontier of the Silurian rocks in Shropshire and Herefordshire, where a true mineral transition is seen to take place between the Upper Ludlow rock and the base of the Old Red Sandstone, there is also a gradual passage from the fossil fishes of the one to those of the other. Thus, even beneath the lowest of the bone-beds of the Upper Ludlow rock, we have the Pteraspis, and again in the bone-bed the Plectrodus mirabilis and Onchus Murchisoni associated with Pterygoti and also with many shells known in the inferior layers. In ascending to a higher stratum most of those mollusks disappear; and, although the same Onchus is still found, we first meet with two species of the genus Cephalaspis added to the Pteraspis in those strata which begin to assume the lithological characters of the Old Red Sandstone. In a word, the Tilestones, or beds of passage, considered in a broad sense, enclose at their base a shell or two and a fish-defence, with crustacea of the Upper Ludlow rock, and in their upper parts, which begin to graduate into cornstones, we first find the characteristic fishes of the Old Red Sandstone. It follows, therefore, that as the grey, flag-like strata which pass up into reddish beds may either be viewed as the termination of the Silurian, or the commencement of the

* The late Lady Gordon Cumming, of Altyre, was the discoverer of many of these fossil fishes, and the exquisite manner in which that accomplished lady and her eldest daughter sketched and coloured them, is duly recorded in the pages of Agassiz's classic work. (See Poissons du Vieux Grès Rouge, *passim*.)

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Old Red, the *genera* Cephalaspis and Pteraspis are typical both of the uppermost Silurian and the lowest zone of the Old Red or Devonian group. In truth, as we now know that the variegated concretions called cornstones are traceable down to within a very few feet of those transition beds, and as the Cephalaspis Lyellii, Pl. 37. f. 1–8, and two species of Pteraspis, id. f. 9 & 10, abound in them, there can no longer be any doubt on this point.

In adopting this view, we remove one of the difficulties which was presented to the mind of Hugh Miller, in his endeavour to determine the order in which the different ichthyolites of the Old Red Sandstone of Scotland successively made their appearance. Grouping the Caithness flagstones in the lower division, and unable, on the one hand, to detect a Cephalaspis in them, or on the other to find the fishes of his north-eastern tracts in the central parts of Scotland, he was naturally induced to suggest, that the beds with Cephalaspis* would be found to lie above the fish-beds of Cromarty and Caithness. In looking, however, to the physical order of the masses in that northern region (section, p. 280), we see that this view cannot be retained; for the bituminous schists of Caithness are comparatively high in the series, and, resting upon a great thickness of sandstone and conglomerate (*a*, *b*, *c*), are overlaid by the upper zone of the group only. According to my view, therefore, as founded also on the natural sections in Shropshire and Herefordshire, the conglomerates and sandstones which underlie the flagstones of Caithness (*a*, *b*, of section, p. 280) are the equivalents in time of the lower cornstone strata of England. This determination is of considerable importance, since good geological text-books, including the last editions of Lyell's Manual and Page's Advanced Text-book, both following Hugh Miller, have placed the Caithness Flags in the lowest division of the Old Red Sandstone.

We may also, indeed, clearly infer, that, even if the Arbroath pavingstones with their Pterygoti do not represent the uppermost Ludlow rocks, still it follows that the Cephalaspis beds of Forfarshire must fall into the lower division of the Old Red group. For a popular acquaintance with the oldest recognized ichthyolites of the Old Red Sandstone, the reader is referred to the figures in Plates 36 & 37.

The bituminous flagstones of Caithness and the Orkneys being considered the central portion of this geological group, we may endeavour to

* In formerly adopting the belief, that the cornstones with Cephalaspis generally represented the middle beds of the Old Red Sandstone, Hugh Miller was quite justified; for it was then supposed, even by myself, that these concretions occupied the central part of the group; whilst we now know that their inferior portion actually graduates downwards into the Tilestones and summit of the Ludlow rock. Again, it was formerly believed that a Dipterus (a marked Caithness genus) had been found in the Upper Ludlow rock. This was a mistake in the original 'Silurian System;' for in no subsequent researches has the smallest fragment of a Dipterus been detected in the bone-bed of the Upper Ludlow rock.

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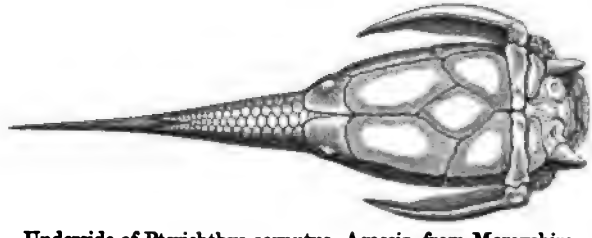
see if there be any cause to serve to explain, why their imbedded ichthyolites, so abundant in the north, should be so rare in the central and southern parts of Scotland. The explanation, it seems to me, is given in the fact, that, as we proceed from north to south, the bituminous and calcareous schists and flagstones so thin out, that already in Nairn and Elgin, and still more at Gamrie, in Banff, such beds are represented by clays with nodules only, and that further southwards even these are no longer traceable in the central portion of the sandstones. The condition, therefore, of the marine waters of the northern seas, and the sediments therein accumulated, must be considered to have specially favoured the life of certain fishes, whose remains are not to be detected when we pass into more southern tracts, where such conditions no longer prevailed.

In the central zone of Caithness and Orkney and its diminished equivalents in Cromarty, Nairn, Elgin, and Banff, are found many species of

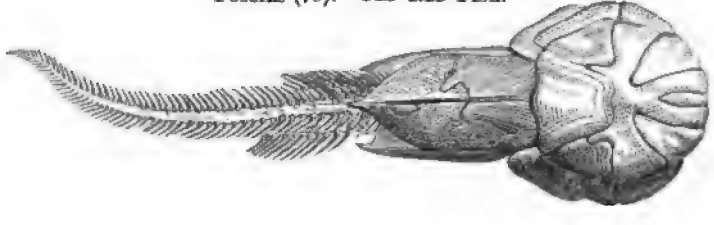
FOSSILS (69). OLD RED SANDSTONE FISH.



Underside of Pterichthys cornutus, Agassiz, from Morayshire.
See the striking description of this ichthyolite by its discoverer, Hugh Miller, 'Old Red Sandstone,' p. 46.

the following genera of Agassiz, viz. Pterichthys, Polyphractus, Coccosteus, Cheiracanthus, Diplacanthus, Cheirolepis, Dipterus, Osteolepis, Diplopterus, and Platygnathus*.

FOSSILS (70). OLD RED FISH.



Coccosteus decipiens, Agassiz, somewhat restored.
A perfectly restored head of this fish is given in Mr. Miller's eloquent work, the 'Footprints of the Creator,' p. 50. Edinburgh, 1850.

* These Caithness fishes were first noticed in 1826 in my memoir on the Coal of Brora in Sutherlandshire, Trans. Geol. Soc., n. s., vol. ii. p. 314; and were placed in their proper geological position in 1827 by Professor Sedgwick and myself. Trans. Geol. Soc. vol. iii., 2nd ser., p. 142. pls. 15, 16, 17. They were partially described and named by Cuvier, who compared them with the Lepidosteus.

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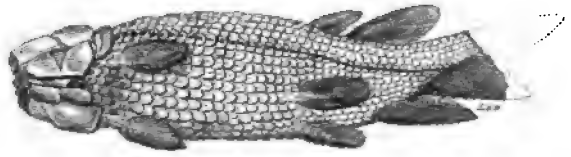
Two of the most peculiar of these forms, the Pterichthys (including Polyphractus) and Coccosteus, were, when first found, considered to be so unlike fishes, that all the skill of Agassiz was required to refer them to that class.

The Coccosteus decipiens, which is here represented, was first put together with consummate talent by Hugh Miller, from several of its detached fragments which that ingenious philosopher collected on the shore of Cromarty.

The other genera above mentioned have more obvious piscine characters. These characters are apparent in fragments even of those fossils which were first published by Sedgwick and myself from the flagstones of Caithness,—such, for example, as the Dipterus and Osteolepis first described by Cuvier at my own request. Another of these fishes is here represented.

FOSSILS (71). OLD RED GANOID FISH.



Dipterus macrolepidotus, Ag., of the black schists of Caithness. From a specimen in the cabinet of Sir Philip de M. Grey Egerton, Bart.

This figure of a specimen in the cabinet of Sir P. Egerton is more correct than that given in my last edition, and, indeed, than any published figure. The extra anal fin supposed to exist in this genus and some allied forms is not seen in this specimen, which shows the ordinary arrangement of a pair of pectoral and a pair of ventral fins, with a single anal fin in advance of the great caudal appendage. Such, no doubt, is the true structure of Dipterus and Diplopterus, which were predaceous Ganoids of the Sauroid family. Their forms, though of great breadth in proportion to their depth (something like that of the Gurnard of our coasts), were compact and graceful.

FOSSILS (72). CRANIUM OF AN ORKNEY FISH.

Frontal portion of the cranium of Diplopterus borealis.

From the dark grey flagstones of Stromness, Orkney.

The breadth and depression of the head in these fishes is well seen in the subjoined small woodcut, which exhibits the frontal portion of the

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cranium of Diplopterus borealis*. The jet-like lustre of some of the Caithness and Orkney ichthyolites and the blackish-purple and dark blue colours of others, make them very conspicuous objects in the grey flagstone.

The central or Caithness flags near Wick have also afforded to the researches of Mr. C. Peach, forms which, resembling shells, have been spoken of as such; but they are now suspected by Mr. Rupert Jones to be the bivalve carapaces of the crustacean genus Estheria, or an allied form.

The bituminous schists of the North of Scotland thinning out in their range southwards, the next member of the series in the central parts of Scotland is specially characterized by other ichthyolites.

In tracing the Old Red group upwards on the southern flank of the Grampians, from the flags or paving-stones of Arbroath, with their Pterygoti and seed-vessels, through the Cephalaspis or lower zone upwards into the deep red overlying sandstones of Perthshire (no bituminous schists being there known), we begin to find the Holoptychius, a genus which has been continued into the Lower Carboniferous rocks. The species, however, which occur in the deep red sandstones of Perthshire, and particularly the splendid specimen from Clashbinnie (H. Nobilissimus, Pl. 37. f. 9), are entirely distinct from those forms which occur in even the highest strata that are observed to pass up into the Carboniferous rocks.

It is only in certain reddish and yellowish sandstones and shales, as seen in Fifeshire, the Lothians, and partially in Ayrshire, that the geologist can be said to enter among those strata which here and there are linked on to the Carboniferous rocks above, as they unquestionably are to the Old Red Sandstone below, and which, according to the predominance of their fossil contents, may be grouped with either deposit. Like the Tilestones which connect the Upper Silurian with the Old Red group, these yellow sands and shales are the true transition beds which unite the Old Red with the Carboniferous series. They are the beds in which Dr. John Fleming long ago pointed out the occurrence of shells and plants indicative of terrestrial and freshwater conditions†.

Other species of Holoptychius occur both in the red-coloured and yellow sandstones on either coast of the South of Scotland; and again, some species of this genus, distinct, however, from all those of the Old Red, are found in the lowest Carboniferous strata.

It is worthy to be again noted, that the only scale of a large species of Holoptychius which I met with in preparing the description of the Silurian region was in one of the upper beds of the Old Red of Here-

* From a specimen found by Dr. Hamilton of Stromness. For the entire cranium see Hugh Miller's Footprints of the Creator, p. 58. He particularly refers to the small central plate in the frontal bone as common to most of the Old Red Ganoids.

† See Edinburgh Journal of Natural Science, vol. iii.

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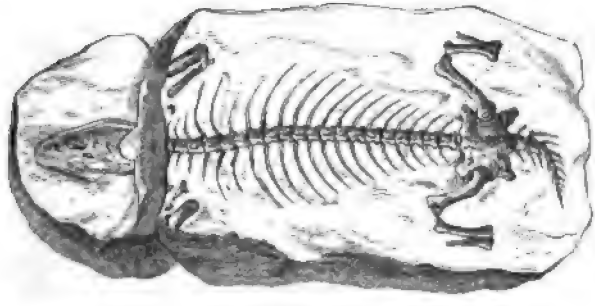
fordshire, near Crickhowell, where that formation passes conformably under the carboniferous limestone of the S. Welsh coal-field. (See Sil. Syst. p. 171.)

These upper beds are marked at Dura Den in Fife, and at Farlow in Shropshire, by the presence of Pterichthys, accompanied in the Scotch locality by Holoptychius. The species, however, are distinct in both cases from those of the older or middle beds in Caithness and the Orkneys, as well as from those of the overlying carboniferous rocks. Among these forms, the Holoptychius Flemingii and Platygnathus Jamesoni, Ag., are common to the uppermost zone of this group in Scotland and in Russia. Besides fishes and certain plants, of which we shall presently speak as ranging up from the Caithness beds into the sandstones of the northern headlands, the upper band of the Old Red of the North of Scotland has yielded the skeleton of the oldest known air-breathing reptile, as here represented.

FOSSILS (73). REPTILE OF THE UPPER OLD RED.



Telerpeton Elginense, Mantell. (Somewhat less than natural size.)

This reptile was found in one of the light-coloured sandstones of Elgin, on the south side of the Murray Frith—strata which, on the whole, form part of the upper division of the Old Red Sandstone, and are superior to the flags and cornstones with ichthyolites. The stratum, however, in which this reptile was found has not been examined by myself, and I therefore rely on the observations of other persons*.

Plants of the Old Red Sandstone.—The most marked addition to the fossil contents of the Old Red Sandstone consists of various fossil plants. Even as late as the year 1854 I could allude to only one unquestionable land plant as having been found in this formation by Hugh Miller, and described by him as a part of a coniferous tree†. The same author had afterwards brought to the notice of the British Association for the

* See Mantell's description of this animal, as found by Mr. P. Duff, of Elgin, and brought into notice in reference to the strata and to certain tracks of an animal in this sandstone, by Capt. Brickenden, Quart. Journ. Geol. Soc. vol. viii. p. 97.

† See 'Footprints of the Creator,' p.198.

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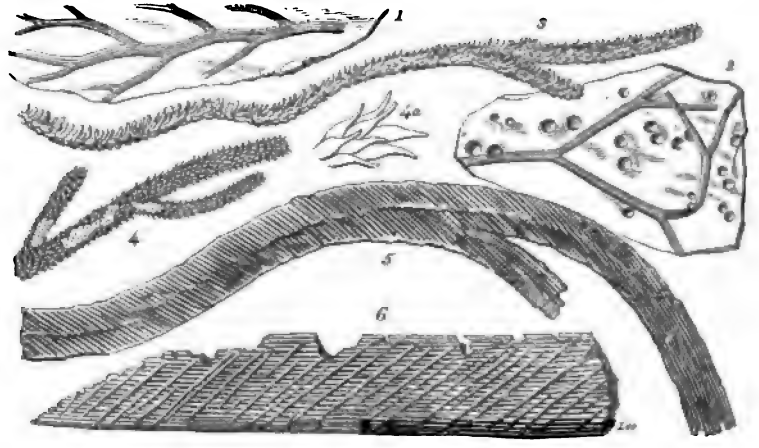
Advancement of Science, in 1855, several of these fossil plants, which have since been published in his posthumous work the 'Testimony of the Rocks.' Most of these have been there referred to tree-ferns, and illustrated in that work by woodcuts*.

Living at Wick, in the central portion of the Caithness flags, Mr. C. Peach has laboured incessantly in that locality to discover organic remains, and has succeeded in disentangling certain fossil vegetables (as well as many ichthyolites) from these hard rocks. The plants are all clearly of terrestrial origin, and are of the same species as those which have been found in the Orkneys by Dr. Hamilton, and at Thurso by Mr. John Miller and Mr. R. Dick, who have collected many excellent specimens near that town†, some of which are figured below.

The most striking, perhaps, of these fossil plants are very large, long, flattened bodies, which, from their state of preservation, were clearly woody stems (Foss. 74. f. 6). They were 4 or 5 inches broad, and as many feet in length, fluted longitudinally, and possessing a central pith.

FOSSILS (74). OLD RED SANDSTONE PLANTS—CAITHNESS.



1. Branched rootlets of some Lycopodiaceous? plant. 2. Dichotomous roots (very common) of Lepidodendron?, upon a surface marked with double annelide-burrows. 3. Lycopodites Milleri, Salter; one-third nat. size. 4. Lepidodendron nothum, Unger?, one-third nat. size. 5. Flattened root, and 6. Fluted stem, of coniferous wood, about one-sixth nat. size.

Though these plants have often been converted into thin plates of crystalline coaly matter, their forms remain distinct, and, under the careful microscopic scrutiny of Professor Quekett, they have exhibited a true coniferous structure. In the arrangement and number of the disks upon

* See Miller's 'Testimony of the Rocks,' pp. 24, 432, &c.

† Most of Mr. Dick's specimens were communicated to the late Hugh Miller; and, when last in Caithness, I induced Mr. John Miller, of Thurso, to send up all his valuable specimens to London for examination. They have now been described by Mr. Salter in the Quart. Journ. Geol. Soc., Nov. 1857, vol. xiv. p. 72. pl. 5.

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the fibres they approach near to the Araucarian group. In general appearance, and even in the mode of preservation, they strikingly resemble certain fossil forms from the Upper Devonian rocks of Saalfeld in Germany, as collected by M. Richter, and hereafter to be noticed—such, for instance, as the Aporoxylon of Professor Unger—but this differs in being of simpler structure, and in possessing no pores or disks.

These fluted fragments are no doubt stems, and similar but more slender specimens found with them are as clearly the branches, which have borne whorls of smaller twigs, like their living representatives. Again, large branching, woody roots, f. 5, but destitute of superficial markings, appear to have belonged to the same trees, and are often several feet long. With these occur very many specimens of a Lepidodendron, f. 4, with scaly, short leaves, L. nothum, Unger?, or a species very like it; a Lycopodites, f. 3, with long prostrate stems and secund or one-sided foliage, like that of the common Lycopodium clavatum. This last may of course be of quite a different natural order, and even coniferous, but its general resemblance alone is implied in the name.

Linear branched or dichotomous fragments*, some of them smooth, f. 1, 2, and destitute of all markings, have also been found, whilst others, like them, are covered with small tubercles in quincunx order, and are probably the roots of the Lepidodendron, f. 4.

The probability of the smooth forms, f. 1, being also roots is very strong. Similar bodies occur in beds of the Upper Devonian series in N. Devon and the South of Ireland, and in such a position with regard to the fluted stems of Knorria, with which they are associated, as to lead to the belief that they are the rootlets of that plant. The larger ones have even markings similar to those of the main stem. These will be referred to in speaking of the Upper Devonian rocks of the Continent.

This probability is strengthened by finding similar linear specimens with them which bear tubercles or excrescences at their tips and along their sides, very like those on the roots of Leguminous plants and many of the Conifers†. The latter is the more probable analogy.

Hugh Miller has, indeed, figured a similar fossil‡ as probably belonging to an ancient marine plant, resembling the Zostera; and has reasonably speculated on the existence of wide fields of such vegetation on the muddy shores of the Old Red period. But our more perfect specimens justify the belief above stated, and as yet there is no evidence of any marine plant in the Caithness schists. The vegetable remains have evidently been swept from adjacent lands into the sea inhabited by the fishes above described§.

* See also Miller's 'Footprints,' p. 193.

† Dr. J. Hooker, Proc. Linn. Soc., No. 58, p. 355*.

‡ Testimony of the Rocks, p. 425.

§ It should also be remembered that Cephalaspis and Pteraspis, both typical Old Red fish, are found with marine forms at Ludlow.

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The flora, on the whole, is analogous to that of the Carboniferous formation, though distinct as to species. In short, there were large Coniferous trees—with whorls of branches and a structure like that of the Norfolk pine, Lepidodendron, Lycopodites, and ferns. That these grew near the coast and were entombed in the shallows of a muddy shore, seems proved from their good preservation and from the nature of the matrix, which is, moreover, indented by the burrows of sea-worms (see f. 2) like those made upon the shores in our own day.

As we advance still higher in the series, or into the strata which overlie the Caithness flags, other fossil plants of large size begin to appear, and several of these have been discovered in the Orkneys and Shetlands by Dr. Hamilton, which, belonging either to Calamites*, or, rather, an allied genus (Bornia), make a near approach to forms usually considered as characteristic of the Carboniferous era.

Devonian Rocks (the equivalents of the Old Red) in Devon and Cornwall.—The crystalline and slaty condition of many of the stratified deposits in Devon and Cornwall, and their association with eruptive rocks and much metalliferous matter, might well induce the earlier geologists to class them among the very oldest deposits of the British Isles. In truth, the south-western extremity of England presented apparently no regular sedimentary succession, by which its grey, slaty schists, marble limestones, and siliceous sandstones could be connected with any one of the British deposits the age of which was well ascertained. The establishment of the Silurian system, and the proofs it afforded of the entire separation of its fossils from those of the Carboniferous era, was the first step in the inquiries which led to a right understanding of the age of these deposits. The next was the proof obtained by Professor Sedgwick and myself, that the 'culm measures' of Devon are truly of the age of the Lower Carboniferous period, and that they graduate downwards into some of the slaty rocks of this region. Hence, in the sequel it became manifest, that the rocks now under consideration were the immediate precursors of the Coal deposits, and stood, therefore, clearly in the place of the Old Red Sandstone of other regions. The highly important deduction, however, of Mr. Lonsdale, that the fossils of the South Devon limestones, as collected by Mr. Austen and others, really constituted a natural-history zoological group intermediate between those of the Silurian rocks and of the carboniferous limestone, was the reason which had most weight with Professor Sedgwick and myself (after identifying North and South Devon) in inducing us to propose the term Devonian†. The stratified rocks of Devonshire and Cornwall, of such varied

* Dr. Hooker, Quart. Geol. Journ. vol. xi. p. 49; see also vol. xiv. p. 73.

† See Report of the British Association for the Advancement of Science, 1836; Sedgwick and Murchison, Trans. Geol. Soc., 2nd ser., vol. v. p. 633, and Phil. Mag. vol. xi. p. 311. See the memoir of Lonsdale, Trans. Geol. Soc., 2nd ser., vol. v. p. 721,

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composition, and which are the equivalents of the Old Red Sandstone in the regions alluded to, have also been illustrated by the researches of Sir Henry De la Beche, Professor Phillips, and other geologists*.

The most instructive of the sections published by my colleague and myself to illustrate the general structure of Devonshire is that of which the diagram at p. 294 is a compiled reduction†. It passes across North Devon from the Foreland on the Bristol Channel to the granitic ridge of Dartmoor on the south, and exhibits a full succession of the Devonian rocks from Linton through Ilfracombe to Barnstaple; the whole dipping under strata of carboniferous age‡, which, on the opposite side of a wide trough, again rise to the surface, resting upon Upper Devonian strata.

The tract of North Devon has thus been selected as affording the best type of succession of the British rocks to which the name Devonian was applied; because it offers a clear ascending section through several thousand feet of varied strata, until we reach other overlying rocks, which are undeniably the bottom beds of the true carboniferous group. For, whether we advance from Barnstaple to the south or from Petherwin to the north (section, p. 294), we find ourselves in a wide §, overlying trough of much softer nature than the flanking tracts, and in which the slaty character is but little developed.

Now, although this overlying series is in mineral aspect as much unlike the carboniferous series of most other parts of Britain, as the rocks of North Devon are unlike the ordinary Old Red Sandstone of England and Scotland, we have proofs by fossils, besides the analogy with Pembrokeshire before spoken of, that the black limestone with Posidonomyæ (or the calcareous band *g* of the section) does represent, on a miniature scale, a part of the Mountain or Carboniferous limestone; that the next series of white grit and sandstone stands in the place of the Millstone grit; and that the overlying courses of culm, with many remains of plants, are consequently the equivalents of some of the lower coal-bearing strata of other tracts to be described in the next chapter||. In

in which our valued friend clearly and modestly states the part which he took in this classification.

* See Report on the Geology of Cornwall, Devon, and W. Somerset, by De la Beche, 1839, and the Paleozoic fossils of the same region, by Prof. Phillips, 1841.

† See Trans. Geol. Soc., 2nd ser., vol. v. pl. 50. figs. 1 & 2.

‡ The coal-field which is bituminous in Monmouth, Glamorgan, and Carmarthen, becomes anthracitic in Pembroke, where the stone-coal strata, much fractured by dislocations, differ from those of Devon only in being much more productive.

§ The thickness of these lower carboniferous strata must not be estimated by the breadth which they occupy on a geological map; for, owing to countless convolutions, the very same beds are repeated over and over in the same broad trough; the folds being well exposed on the coast. See Trans. Geol. Soc. *loc. cit.* The bottom beds only of these undulations, or small portions of each side of the culm trough (*g*), are represented in the section.

|| Some of the culm beds of Devon may be considered as subordinate to the millstone grit, but I believe that much of the culm overlies that rock, and is simply the equivalent of the culm of Pembrokeshire, of which hereafter.

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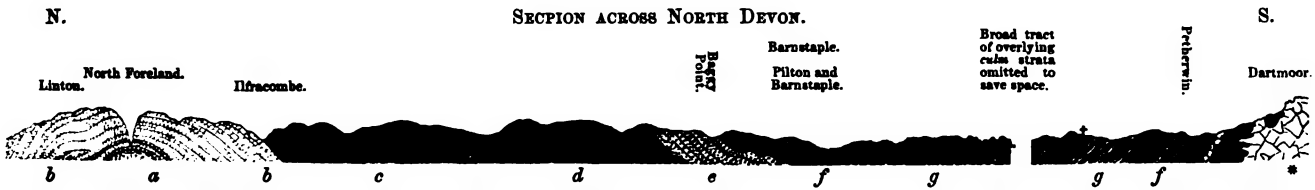

a. Lowest beds of schist and red micaceous sandstone. *b*. Red sandstone and conglomerate. *c*. Grey schists and Stringocephalus limestone. *d*. Quartzose schists. *e*. Arenaceous rocks (Marwood sandstones), red and brown. *f*. Upper Devonian bands, with Clymenia limestone. *g*. Trough of culm or coal; a black limestone with Posidonomya near its base, overlaid by grits, schists, and culm; the whole representing the Carboniferous series. * Eruptive granite of Dartmoor.

The lowest of these Devonian rocks, *a*, are hard, close-grained, greenish and reddish, siliceous, and slightly micaceous sandstones, by no means unlike parts of the Old Red of Pembrokeshire, on the opposite side of the Bristol Channel (see p. 303). Associated with them are chloritic schists, occasionally calcareous, and enclosing corals and also shells, such as Spirifer ostiolatus, S. aperturatus, and Orthidæ, usually much distorted by slaty cleavage†. Then follow thick coarser beds, *b*, red and purple, which here and there pass into red conglomerates; whilst some bands are flag-like and spotted, and others are white sandstones. They occasionally contain fragments of the older schists, and many are highly impregnated with red oxide of iron and hæmatite. "Considered as a whole, and from mineral characters, we might compare some parts of this group with the most characteristic portions of the Old Red Sandstone." (Sedgw. and Murch. Trans. Geol. Soc., n. s., vol. v. p. 145.)‡

These red rocks, *a*, *b*, the representatives apparently of the lower shelly 'greywacke' of the Rhine (Coblentz, &c.), are of considerable thickness, and are distinctly overlaid on the south by grey slaty schists, *c*, in which calcareous geodes are frequent, occasionally ranging through some thickness. One band of limestone at Combe Martin has the dimensions of 60 feet, and is surmounted by eight or nine other courses of smaller dimensions. They contain remains of shells, including Stringocephalus giganteus, and many corals known elsewhere, such as Cyathophyllum cæspitosum and Favosites polymorpha. Most of the fossils, however, are so disturbed by cleavage and pressure, that we can speak confidently only of the species when these remains are found in rocks of the same age in South Devon, where the limestones are purer and the schists crystalline.

The calcareous group of Ilfracombe is succeeded on the south by hard, slaty, grey, and chloritic schists, without limestone, *d*, but with many veinstones of quartz; these, again, are surmounted by softer schist, with reddish sandstone, and greenish-grey and purplish flagstone. Then follow the arenaceous flagstones, *e*, of Baggy Point and Marwood, which are much more earthy than the underlying rocks, and contain Cucullæa, Avicula Damoniensis, and remains of land plants. Here again, even, we have a *partial return to the character of the Old Red Sandstone*, for the brown and grey flagstones often pass into a red sandstone, hardly to be distinguished from the inferior red rock, *a*, *b*, of Linton; whilst others are of greenish-grey and brownish sandstone, resembling varieties of the Upper Old Red Sandstone of Scotland. The calcareous group, *f*, of Pilton and Petherwin completes the Devonian series, and even contains fossils which link it on to the Lower Carboniferous. It is surmounted by true carboniferous schists, *g*, with the Posidonomya limestone, which is a thin representative of the carboniferous or mountain limestone, and is followed by grits and beds of culm, representing the Millstone grit series of other parts of England.

† See the able memoir of Mr. D. Sharpe, on the effects of slaty cleavage on the form and outline of several of the Devonian shells, Quart. Journ. Geol. Soc. vol. ii. p. 74.

‡ The same succession of strata (as that described from the North Foreland to Barnstaple) ranges throughout the Quantock Hills, as we learn from the collections made by the late Rev. D. Williams (which are now in the Museum at Taunton) and by sections drawn by Mr. J. D. Pring of that town. The Favosites polymorpha and Atrypa desquamata are common in the upper or southern portions. I have myself traced these beds in a rude manner through the Quantock Hills.

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short, no one denies that in the culm series of Devonshire we have the representatives of the lower carboniferous strata.

The objections, therefore (which have, however, been only very partially made), to the view taken by Professor Sedgwick and myself, that the Devonian rocks of the foregoing section are the true representatives *in time* of the great deposits of Old Red Sandstone of other parts, are quite untenable. In truth, the long period which was occupied in developing the enormously thick Old Red deposits must have produced equivalent accumulations elsewhere; and the vast series of North Devon immediately underlying the lowest Carboniferous beds occupies precisely the same position as the Old Red Sandstone of central England and Scotland. Moreover, as every geologist knows, that the crystalline feature of slaty cleavage was impressed upon these Devonian rocks long after their formation, so must he also admit, that the change from the red sand and shale of Hereford, Brecknock, and Carmarthen to the grey shale with some red sand in Devon, is by no means abrupt, but resembles the gradual change which begins to take place in Pembroke. Nor is there any difficulty in supposing, how, by a less diffusion of iron, and under dissimilar submarine conditions, the southern portion of the area of the very same sea should have less of the red and sandy character than the northern.

But if, on account of lithological distinctions, some persons should persist in denying that the slaty rocks of Devonshire can be the equivalents of the red sandstone and shale of the Silurian region, let it be recollected that this change in lithological structure is by no means more remarkable than the mutation of aspect and character which the next overlying or Carboniferous formation has also undergone in Devonshire. For, in no distant parts of the world do two coal formations of like age present mineral and zoological characters more entirely unlike each other, than does the great S. Welsh basin of Glamorganshire, when compared with the Culm region of Devonshire, though separated by the Bristol Channel only. This point will be further illustrated in the next chapter, and afterwards in pointing out the variations of mineral character in these deposits in different parts of the world.

The great eruption of the granite of Dartmoor, which affected both the Devonian and Carboniferous strata in contact with it, has so usurped the place of the regular deposits in South Devon, that in vain do we look, either there or in Cornwall, for the same clear order as in North Devon. In fact, the derangement in the western portion of South Devon and the adjacent parts of Cornwall is so great, that the Lower Silurian rocks are seen, as already stated, to overlie true Devonian rocks! * The metamorphism of some of the schists has, indeed, often given to them the semblance of the oldest primary rocks.

* See p. 161, and Quart. Journ. Geol. Soc. vol. viii. p. 13.

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Still, there are adequate means of bringing the disjointed and occasionally inverted masses of South Devon into comparison with the clear order of North Devon. This is in great measure owing to the numerous and well-preserved fossils* of its extensive lower limestone. The lowest limestones, for example, which are on the parallel of those of Combe Martin and Ilfracombe (*c* of the long section), and rise in great masses near Plymouth and Ogwell, ranging at intervals to Newton Bushell and Torquay†, are laden with corals and shells, many species of which occur in rocks of the same age in various parts of the continent of Europe, and notably in the limestones of the Eifel, the Rhenish provinces, and Belgium. Now, many of these fossils are quite peculiar; for, whilst they exhibit an intermediate character, approaching in the lower beds of this series to those of the Silurian system, though almost all distinct, and in the upper strata to those of the Carboniferous era, there can be no doubt that, on the whole, they constitute an independent group. These corals have been described in the Memoirs of the Palæontographical Society of 1853 by MM. Milne-Edwards and Jules Haime‡.

All the species of Trilobites known in the Silurian system have dis-

* The differences between the *mineral* succession in North and South Devon, on the opposite sides of the great granitic axis of Dartmoor, are explained by Sedgwick and myself, Trans. Geol. Soc., 2nd ser., vol. v. pt. 3. p. 635.

† One of the finest collections of the S. Devon fossils was made by Mr. R. A. Godwin-Austen, whose researches in the field, and whose study of the organic remains, so materially contributed to a correct acquaintance with the stratified rocks of Devonshire. See Trans. Geol. Soc., 2nd ser., vol. vi. p. 433; and Lonsdale, ibid. vol. v. p. 721.

In a Memoir on the paleozoic rocks of the Boulonnais (Quart. Journ. Geol. Soc. vol. ix. p. 244), Mr. Austen classes the Petherwin and Pilton beds, like myself, with the Devonian rocks, whilst he separates the S. Devon limestones of Newton and Ogwell from those of Ashburton, Bickerton, and Chudleigh. If in this popular work I retain the older view, and group together the S. Devon limestones, I would in no respect detract from the value of such a subdivision. My present belief is, indeed, that the lower sandstones, conglomerates, and slates (or the *a b* of the previous section) are truly the equivalents of the Lower Rhenish or Coblentzian, shelly, 'greywacke' sandstone; thus completing the parallel between the British and Rhenish Devonian rocks, and giving to each a similar base. In respect to the Upper Devonian division, all foreign geologists who classify by organic remains, including M. de Koninck, whose opinions will be cited in a subsequent chapter, have placed the Clymenia and Cypridina limestone in the Devonian system. I must therefore entirely dissent from a proposal of the late Mr. D. Sharpe, to remove this band to the base of the carboniferous rocks. But, if an *intermediate* band like this may in one region present more of a carboniferous type than in another, and therefore admit of much liberty in drawing the exact line of separation, I can still less admit the comparison sought to be established by the same author, between a few unfossiliferous Belgian beds of red sandstone, shale, and conglomerate (which at Pepinster, in Belgium, form a *very small* portion indeed of the series of Devonian rocks), and the enormous deposit of the Old Red Sandstone of the British Isles, which, without any break, occupies in many tracts the whole of the vast interval between the Silurian and carboniferous rocks. See Sharpe, Quart. Journ. Geol. Soc. vol. ix. p. 23.

‡ I find that my friend Mr. Lonsdale does not participate in the opinion of these authors respecting some of the corals which they refer to the genus Favosites. I earnestly trust that his health will permit him to publish a Report on the Corals from the Paleozoic Formations of New South Wales, transmitted to him by the Rev. W. Clark, in which he will assign, I doubt not, valid reasons for the distinctions he draws.

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appeared, and their places are taken by others, of which Bronteus flabellifer, Goldfuss, Phacops latifrons, Bronn, and P. laciniatus, Roemer, are striking types both in Britain and on the Continent. Large species of Homalonotus, different from the Ludlow rock species, being ornamented with spines, characterize the lowest beds. They are found, too, in Devonian strata of very distant regions, *e. g.* the Cape of Good Hope. Trilobites, however, which swarmed in Silurian times, were comparatively scarce in the Devonian; although several of the very numerous genera of the former era are known in it, and no new genera are introduced.

Among the mollusca, nearly all the species of Atrypa, Orthis, and Spirifer differ from those of the Silurian era*. One shell, however, the Atrypa reticularis, must be mentioned as an exception to the prevalent rule of each great group being distinguished by peculiar forms; for this hardy species, with which the reader became so familiar in the Silurian rocks (see p. 231), lived on to the Devonian era, and is as common in the limestones and shale of Devonshire as in the older series. It even ranges to the furthest known geographical limits of the Devonian rocks, —to Armenia, the Caucasus, and China on the east, and to the Devonian deposits of America on the west!

Although many of the Silurian and Devonian genera are the same, yet the proportional number of species is very different, and certain genera of shells which were common in the older period are no longer traceable. Thus, the genus Orthis becomes far less abundant, whilst the Spirifer, comparatively rare in the older rocks, augments much in number of forms, and especially in the size of the shell—the large broad-winged Spirifers being especially characteristic of rocks of this age, and particularly in the Lower Devonian of several foreign countries. Several species common in the sandstones of Torquay and Fowey in S. Devon and Cornwall, are, indeed, well known in the Rhenish provinces. Such, for example, are Spirifer macropterus, Goldf., S. speciosus, Schl., and S. lævicosta, Valenc. (S. ostiolatus, Schl.), Chonetes semiradiata, C. sarcinulata, and the Orthis circularis, Sow. In Britain, no brachiopod is more typical than Atrypa desquamata, Foss. 75. f. 5.

Tentaculites annulatus, Schl., Homalonotus (probably armatus, Burm.) with spines, and the remarkable Rhenish coral Pleurodictyum problematicum, are among the characteristic species of the lowest beds.

As if to draw the parallel even still closer between Devonshire and the Rhine, Bactrites (Orthoceras) gracilis, Münster, the prevailing fossil of the Wissenbach slates, (which, as will hereafter be seen, occupy a low position in the series,) has been found at Black Head near St. Austell.

The most typical shells which mark the strata in which they occur as of middle Devonian age, are the large Stringocephalus giganteus,

* Many Silurian species appear, indeed, in catalogues of Devonian fossils; but in most cases it is believed (with the exception of a few corals) erroneously.

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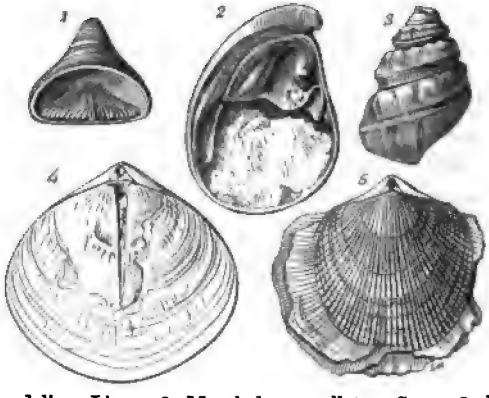
Foss. 75. f. 4, Megalodon cucullatus, f. 2, and Calceola sandalina, f. 1, represented in the following woodcut, together with Murchisonia bilineata, f. 3, and the corals Cyathophyllum cæspitosum, Heliolites pyriformis, &c.

To these few characteristic fossils the following may be added as abounding in the limestones of Plymouth, Berry Head, Teignmouth, Ogwell, and part, at least, of those of Newton Bushel*,—viz. Spirifer

FOSSILS (75). SHELLS OF THE CENTRAL OR GREAT DEVONIAN LIMESTONES.



1. Calceola sandalina, Linn. 2. Megalodon cucullatus, Sow. 3. Murchisonia bilineata, Goldf. 4. Stringocephalus giganteus, Sow. 5. Atrypa desquamata, Sow.

speciosus, S. heteroclytus, Defrance, Pentamerus brevirostris, Cyrtoceras ornatum, Goldf., &c.; species of Scoliostoma (or Vermetus?), Euomphalus annulatus, Goldf., Pleurotomaria, Macrocheilus, Loxonema, Pileopsis, and Porcellia; Encrinites (Hexacrinus, Platycrinus, &c.); with the species of trilobites, Bronteus, Phacops, and Harpes macrocephalus, &c. first mentioned.

The curious fossil called Sphæronites tessellatus by Sir H. De la Beche also occurs here. It is not, however, a Cystidean, that family being confined to the Silurian rocks, but is, perhaps, a complex sponge, as is also the Steganodictyum of M'Coy, from the slates of Polperro, Cornwall. The fossils of the calcareous slates, indeed, which range throughout S. Devon and S. Cornwall, are for the most part the same as those of the limestones; Atrypa desquamata and Phacops laciniatus being the commonest forms at Padstow, Liskeard, and St. Keyne.

To return to the section, p. 294. The highest rock which is there classed as Devonian, and which is, on the whole, a mere upward continuation of the slaty series, differs very considerably on the two sides of the

* The higher beds at Newton Bushel are certainly of newer date, the characteristic shell being the Rhynchonella cuboides, Sow., a species which characterizes the beds immediately below the Clymenia limestones of Germany and Belgium. A species of Chiton (the elongate form, Helminthochiton) is also found in the Newton Bushel beds.

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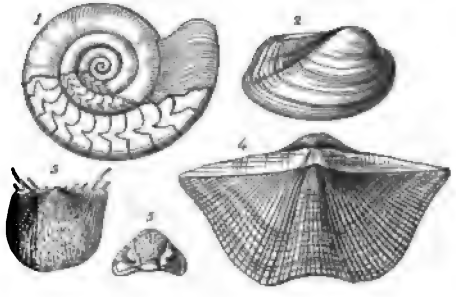
trough; so much so, that there is considerable difficulty in identifying the beds on the southern side of the trough with those on the northern. On the southern side the strata, by their schistose and calcareous nature, truly represent the Upper Devonian limestones and schists of Germany, of which mention will be made in a subsequent chapter; but the beds of the Barnstaple section differ much in lithological character and fossil contents, and indicate, both in my opinion and in that of Mr. Salter, who re-examined them carefully, a somewhat higher series.

To begin with the beds of Petherwin in Cornwall. Here the uppermost beds, underlying the trough of the culm strata, consist of soft, fissile grey slate, with some courses of impure limestone, *f*, as expressed in the previous section. In this band a great number of fossils have been found; and these, whatever ambiguity may attach to the beds of Barnstaple, clearly identify the Petherwin series with the Upper Devonian of many parts of the continent of Europe. Such are the Phacops granulatus, Foss. 76. f. 5; Clymenia linearis, f. 1; C. lævigata, Münster;

FOSSILS (76). SHELLS OF THE UPPER DEVONIAN.



1. Clymenia linearis, Münst. 2. Cucullæa Hardingii, Sow. 3. Strophalosia caperata, Sow. 4. Spirifer disjunctus, Sow. (Verneuilii, Murch.). 5. Phacops granulatus, Münst.

C. striata, Münster; Goniatites subsulcatus, Münster; Cardiola retrostriata, V. Buch, and the Productus subaculeatus, Murch. These fossils are not found in the Barnstaple series. Several species (probably 14 or 15), however, are met with in both localities. Spirifer Urii, for instance, and Orthis interlineata are common fossils, and these, with the Spirifer disjunctus, or Verneuilii, a Devonian fossil of the Boulonnais, help to connect these beds with those on the north side of the culm trough. On the other hand, the characteristic trilobite Phacops latifrons, so common at Barnstaple, is absent from the Petherwin deposits*.

* It is present in a small outlier of slaty rock which pierces the culm a few miles N. of Launceston, and is there accompanied by Petraia Celtica. This outlier was observed many years ago by Mr. S. R. Pattison, and has been again lately examined by Mr. Salter, who was unable to obtain satisfactory evidence of its being higher in position than the Petherwin limestone. He is, however, strongly inclined to that opinion, both from its position and organic contents.

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The most typical portion of the Upper Devonian beds of Barnstaple is the calcareous band of Pilton and Brushford, and which ranges by Heaton and Braunton to the sea at Croyde Bay. Now, whilst the lower sandy strata of this section, as at Marwood and Baggy Point, contain numerous Cucullææ, chiefly C. Hardingii, Foss. 76. f. 2, and C. trapezium, Sow., Bellerophon subglobatus, M'Coy, and a peculiar species like the B. trilobatus of the Tilestones (B. bisulcatus of Rœmer), with casts of land plants, such as Knorria dichotoma, a species of Bornia, &c.,—the upper or calcareous part is charged with a true Devonian trilobite, the Phacops latifrons, Bronn, together with species of Pleurotomaria, Orthis, Spirifer, Terebratula, and Strophalosia, some of which occur in the carboniferous rocks, but others are Upper Devonian. Such are the Spirifer Verneuilii and the Strophalosia caperata. The Productus prælongus, Sow., is a species elsewhere unknown, but occurring in profusion in these beds. With this, too, is the Spirifer Barumensis, also a local form, resembling S. cuspidatus of the carboniferous limestone; and there are fossils of that formation—Spirifer Urii and Rhynchonella pleurodon; together with Fenestellæ, encrinites, fish-pellets, &c., which appear to be identical with those of the Carboniferous slate. Here, again, though with considerable mineral variations, we see the same upward succession as in Scotland and Ireland, and in approaching the summit of what has been classed as Devonian or Old Red, we are gradually introduced to the flora and fauna of the Carboniferous era.

It has been proposed, indeed, to classify the whole of these Upper Devonian deposits with the Carboniferous system, the late Mr. D. Sharpe and Mr. Godwin-Austen having advocated this view. Mr. Salter inclines to a more modified opinion, and while classifying the upper portion of the Barnstaple group with the Lower Carboniferous limestone shales of Smith, regards the Marwood beds* as the uppermost part of the Devonian series, and as beds of transition downwards into the Upper Old Red Sandstone, of which the Petherwin series is perhaps the true marine type.

This Upper Devonian of South Britain, which occupies, in my opinion, the same place in the geological series as the uppermost red sandstones flanking the Silurian region, and the sandstones with plants of the North of Scotland, is well represented by the beds of Petherwin (*f* of the section, p. 294), while perhaps a somewhat higher member of the series is included in the Barnstaple and Marwood series.

In addition to Phacops granulatus, Clymeniæ, and other fossils above mentioned, the Petherwin beds are also marked by the presence of a minute crustacean, Cypridina serratostriata, Sandb., which will be much spoken of in treating of the Upper Devonian rocks of Germany (Chap-

* In the South of Ireland these Marwood beds are exactly represented by the 'Coomhola Grits,' of which hereafter.

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ters 14 & 15). The discovery in Britain of this small crustacean was made long after the distinguished paleontologists, the Sandbergers, had found it in myriads occupying the upper schistose and calcareous rocks of the Rhine, which Professor Sedgwick and myself had formerly shown to pass immediately under the lowest carboniferous deposit, and to be the true equivalents of our Upper Devonian rocks. The observation of F. Sandberger (for he first detected this Cypridina in British rock-specimens sent to him) has therefore been peculiarly valuable, as, by means of this minute but characteristic crustacean, we now learn conclusively, that the limits of the Devonian rocks in S. Britain have been correctly defined; their equivalents in Germany being similarly distinguished by fossils.

Devonian Rocks in Ireland.—In describing the Upper Silurian rocks of the Dingle promontory in Ireland, p. 189, a general section was given, with allusions to the labours of Griffith, and to those of Jukes and Du Noyer, of the Irish Geological Survey, to show that the strata containing Wenlock and Ludlow fossils there graduate conformably upwards into a vast thickness of schistose and thin-bedded sandstones of purple and greenish colours, surmounted by conglomerates, which, from the position they occupy, must, in my opinion, represent *in time* the great mass of the Devonian rocks of some countries and of the Old Red Sandstone of others. The greenish and purple flagstones immediately surmounting the Ludlow rocks, are followed by a great thickness of those hard, green, quartzose, coarse, gritty rocks, with interlaminated slaty layers, to which the name of Glengariff Grits has recently been assigned. From their hard and semi-crystalline character, whether they be examined in the Dingle peninsula*, at Glengariff, or in the lofty mountains (including Macgillicuddy's Reeks) around the Lakes of Killarney, it is little likely that fossils will be detected in them. They usually, indeed, assume that aspect which by old geologists would have been considered best designated as 'grauwacke.'

These purple and greenish grits are first overlaid conformably (at least near Dingle) by sandstones and conglomerates of considerable thickness, to which has been recently assigned the local name of 'Dingle beds.' All these, however, constitute one physical mass, the lower part of which, being welded on to the Upper Silurian by thin fissile strata above noted, may pass for the tilestones of the Silurian region of England and Wales; whilst the chief superior masses probably represent a portion of the group in which 'Cornstones' abound in Shropshire and Herefordshire, or some of the chief masses of this age which, in Devonshire, are slaty and gritty. Although there are some very coarse representatives of cornstones, calcareous matter is, on the

* I use the term 'Dingle Peninsula' as most expressive of the rocky mass which lies between the Bays of Dingle and Tralee.

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whole, very scarce, whilst nothing like the great limestones of Devon has been detected.

Let me here, however, observe, that on the continent of Europe there are many large accumulations of similar *un*fossiliferous rocks with an equally antique aspect, which occupy exactly this place in the geological series. Thus, amidst the slaty and siliceous Devonian rocks of the Rhine, there are vast thicknesses of strata wherein no organic remains have yet been detected; their age being only made known by a rare calcareous or fossil-bearing course.

There can, indeed, be no ambiguity in assigning to these vastly thick Irish rocks, immediately and conformably surmounting the unquestionable uppermost Silurian, their true *stratigraphical* place; particularly when we see that they are covered not only by a very full series of carboniferous rocks, but also by intermediate red conglomerate and sandstone of great thickness, to which, in Ireland, the term Old Red Sandstone has hitherto been exclusively applied.

This is the red conglomerate and sandstone (*z*) of the section, p. 189, which, overlapping conformably different members of the underlying rocks, is itself conformably overlaid by the carboniferous rocks of the South of Ireland, of which it forms the natural foundation. Seeing the great rupture between this red sandstone and conglomerate and all that is subjacent, Mr. Jukes and other geologists have been led to class it with the lower carboniferous rocks, including the yellow sandstone and lower limestone shale and slate of Griffith, to which it is conformable; and, if the organic remains which occur in these red rocks had been found to accord with carboniferous types, the suggestion might be adopted. But the characteristic fossils of the superjacent dark grey and carbonaceous beds, such as the Rhynchonella (Terebratula) pleurodon and Spirifer cuspidatus, have nowhere been detected in these red strata; the only remains which might seem to connect them with the overlying carboniferous strata being certain fragments of plants, apparently common to both, though of these even no mutual specific identity has yet been established.

On the other hand it must be stated, that these same beds, particularly in the district of Kiltorkan, contain species of fossils wholly unknown in the carboniferous rocks. Such are some peculiar Lycopodiaceous plants, the fern originally called Cyclopteris, now Sphenopteris, Hibernica, and the large freshwater shell, Anodon Jukesii, Forbes.

The plant, a figure of which is here given, Foss. 77, was described in 1852 by Edward Forbes, as the remains of one of the oldest tree-ferns then known to us, and as essentially distinct from any plant of the Coal period.

Again, in these strata, the teeth of a Dendrodus and one of the dermal plates of a Coccosteus have also been found, both of them fishes known in the Old Red or Devonian period only.

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These beds, like the Upper Old Red in many other countries, simply form a natural transition into the Carboniferous system.

A discordance in stratigraphical arrangement in one portion of a country only, cannot set aside the well-recorded sequence (without any sort of break) seen in the other parts of Britain already described. For, if the fossils of the overlying mass agree most with those of the true

FOSSILS (77). OLD RED SANDSTONE PLANT.

Cyclopteris Hibernica, Forbes, Report Brit. Assoc. 1852.

From specimens in the collection of the Geol. Survey.

Old Red Sandstone, it is obvious that notwithstanding the break which separates the Glengariff grits from the Red Sandstone of these discordant members, both must be grouped together.

There can be no better illustration of this paleontological axiom, than the fact now generally recognized throughout Germany and France; viz. that the Lower Carboniferous rocks, though perfectly and conformably united with the subjacent Devonian rocks, are completely separated from them by fossil remains. On the other hand, there has been throughout those regions a great and general break between the Lower Carboniferous, or the series which represents our Mountain Limestone and Millstone Grit, and the younger or overlying coal deposits; and yet the carboniferous group is always viewed as a whole on account of the general agreement of its fossils, both animal and vegetable.

Until proofs, therefore, are brought forward to show that the rocks in Ireland hitherto termed Old Red, should, by their fossils, be classed with the Carboniferous system, I shall continue to range them as the clear equivalents of the upper division of the Old Red of the N.E. of Scotland, including the Orkney and Shetland Islands, and as being also of the same age as the Petherwin beds in Devonshire, and of the plant-bearing Cypridinen-Schiefer or uppermost Devonian of Germany,—a band which in the two latter countries is united downwards with the Devonian rocks, and upwards with the lowest carboniferous strata.

In this view, a *hiatus* is, indeed, to be accounted for in Ireland which is unknown in the Silurian region of England, as well as in the parts of Scotland alluded to. Nor, in the absence of fossils, can the amount of the omission be properly estimated. But, notwithstanding this discrepancy, the great fact remains undisputed—that the series of Glengariff schists and grits, as well as their unconformable cap of sandstone and conglomerate, are all clearly intercalated between the unquestionable uppermost Silurian rocks, and the lowest stratum charged with those

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characteristic plants and shells by which geologists recognize the Carboniferous system.

In subsequent chapters we shall see, that when the Devonian rocks are much developed in different parts of Europe, and in the Rhenish provinces especially, they are divisible into three parts, as in Scotland and England*. It will further appear, how, in other tracts, and particularly in Russia, the ichthyolites of the Old Red Sandstone of Scotland and the *marine* shells of Devonshire, Germany, France, and Spain, are found united in the same strata; thus demonstrating the synchronous accumulation of deposits, which, although they differ considerably in mineral aspect, occupy precisely the same stratigraphical place in the general series of deposits.

In quitting the consideration of the highly diversified and important group of the Devonian rocks or Old Red Sandstone of the British Isles, it must not be forgotten, that whilst some of its lowest members have rarely afforded traces of land plants, its central and upper parts in Ireland, Devonshire, Scotland, and Shetland contain numerous vegetable remains, including tree-ferns and probably Calamites. We must equally remember, that the latter plants are associated, particularly in Scotland, with some of the peculiar ichthyolites of this epoch, and occur in strata which rise out from beneath the lowest beds of the carboniferous rocks. Besides, in ascending, we also first meet in this stage with that assemblage of natural products which might be expected; for the most ancient air-breathing reptile which has been discovered, is the legitimate associate of this early land vegetation.

Other and much more numerous terrestrial plants of this period will be afterwards adverted to as occurring near Saalfeld in Germany. In fact, the uppermost member of the Devonian and the lowest of the Carboniferous are sometimes so linked together, that it is no easy matter (and particularly where the carboniferous limestone is wanting) to draw any positive line of zoological or botanical separation between these groups. Such results must, indeed, have invariably followed from the operation of natural causes, wherever great subaqueous deposits were quietly and successively accumulated.

* See the triple division of the Devonian rocks by Sir C. Lyell, Manual of Elementary Geology, p. 424.

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CHAPTER XII.

CARBONIFEROUS ROCKS.

GREAT PRIMEVAL FLORA THE SOURCE OF THE OLD COAL DEPOSITS.—GENERAL VIEW OF THESE DEPOSITS AND THEIR ORGANIC REMAINS IN THE BRITISH ISLES.

ASCENDING in the scale of deposits, we have now reached another grand accumulation of strata, which is not only replete with many types of animal life peculiar to it and unknown in antecedent periods, but is specially characterized by the earliest abundant remains of a terrestrial vegetation. The reader will remember, that the feeblest traces only of land plants have been discovered in the great mass of the Silurian rocks; and that, even where their uppermost strata unite with the Devonian, they have been very sparingly found. In the Devonian rocks, also, such remains, as before stated, are comparatively rare, and only begin to abound when we have passed upwards and are surrounded by the spoils of the oldest extensive forests with which we are acquainted.

Now, as these primeval plants were the substances out of which the great mass of the mineral termed coal has been formed (all naturalists and chemists admitting the fact), so we meet for the first time, in mounting up from the basement rocks, with the impressions and casts in stone of numerous plants. Some idea of the

IDEAL VIEW OF THE VEGETATION OF THE CARBONIFEROUS ERA.

characters of the rank, luxuriant vegetation which must in this age have overspread very wide areas of land, from polar to nearly equatorial latitudes, may be formed by inspecting the annexed woodcut,

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in which an ideal representation is given of a portion of the earth's surface, as clothed with plants, the fragments of which bespeak a rich flora of vascular Cryptogamia, fossilized stems and leaves of which are frequently to be detected even in the coal itself. In the standard work of Bronn, von Meyer, and Göppert, which gives the most complete, general tabular view of ancient nature hitherto published*, Professor Göppert estimates the total number of known species of fossil plants of what is here considered as the Carboniferous era, as 934, which are thus distributed:—

PLANTÆ 934.—*Cellulares*, including the Fungi, Algæ, &c., 19; *Vasculares*, 915; of which 772 are cryptogamous plants, or Ferns, Calamites, Asterophyllites; and 94 are phanerogamous plants, such as Cycads, Conifers, &c.

The result arrived at by this botanist agrees generally with that of his precursor in this line of inquiry, M. Adolphe Brongniart, who first gave to the world a general and philosophical view of the distribution of former vegetation. On his part M. Göppert has not only added considerably to the number of species, but also to the number of coniferous or forest trees.

Both, however, of these eminent men, as well as many other botanists, are agreed in the opinion, that as the great mass of the plants belong to the vascular cryptogamic class, the conditions of climate under which such vegetables grew in very various latitudes is a phenomenon *per se*, and especially characteristic of the Carboniferous period. These plants are, in fact, as decisive of the Carboniferous period, as the Trilobites and Graptolites are of the Silurian era. But, whilst the earlier system is marked by its submarine contents only, the carboniferous deposits owe their chief features to the actual presence or contiguity of lands covered with a peculiar vegetation, which, disappearing with the youngest primeval strata, now called Permian, was never afterwards reproduced upon the earth. For, no one of the floras of subsequent geological periods possessed those characteristic features of rank, gigantic Cryptogamia, indicative of a peculiar, if not an intertropical climate, which so prominently marked the vegetation of the earliest great woody epoch.

* Bronn's Geschichte der Natur, vol. iii. part 2. The so-called 'Transition' plants of Göppert are included in this list; because it has been ascertained that nearly all of them occur in strata which, formerly viewed as ancient '*grauwacke*,' are now known to be of no higher antiquity than the lower division of the Carboniferous rocks.

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In most of their stony characters the successive strata of the Carboniferous rocks do not differ essentially from many which had preceded them. Like the Silurian and Devonian, they contain beds of shale, sandstone, pebbles or conglomerate, and limestone, though they seldom exhibit a true slaty cleavage*. But, when examined more in detail, they vary considerably in their nature and contents in different parts of the world. In subsequent chapters a few allusions will be made to these variations in other countries; but for the present we will take a cursory view of some of their features only in Britain.

Ascending order—Lower Carboniferous of Great Britain.—In the region represented in the map annexed to this work, the carboniferous rocks are most fully developed in the great South Welsh basin of Caermarthen, Glamorgan, and Monmouth, where an ascending order from the summit of the Old Red Sandstone, through shale, limestone, sandstone, and grits, upwards into an enormously thick coal-field, is clearly exhibited in lofty escarpments, particularly around the northern, eastern, and western edges of that grand basin. The same succession, though on a minor scale, is seen around the smaller basin of the Forest of Dean, and again, with certain mineral variations, and an expansion of the lower shale, in the county of Pembroke.

Towards the north, the calcareous and lower members of the series are more developed, as observed in the Oswestry coal-field, and in Shropshire and Flintshire, than in most parts of South Wales. This expansion of the inferior zone of these rocks towards the north becomes still more striking in the range of the strata from Derbyshire into Yorkshire and Northumberland, and, particularly, in the south and central districts of Scotland.

In some of the coal tracts within or adjacent to the Silurian region, as at Dudley and Wolverhampton, the whole base and central mass of the group, or the carboniferous shale and limestone, are wanting; the upper productive fields there reposing at once on Silurian rocks (see woodcut, Sil. Syst. p. 465). In those districts, however, and along the banks of the Severn, good evidences are obtained of the relations of the coal strata to the overlying red deposits now termed Permian, of which hereafter.

When viewed, therefore, as a whole, and *in the region of the coloured*

* In parts of France the carboniferous rocks are very crystalline and slaty, as I have shown in a memoir on the environs of Vichy: Quart. Journ. Geol. Soc. vol. vii. p. 14. In some of these much dislocated, schistose, and greywacke-like rocks of the Sichon, I obtained specimens of Chonetes, Phillipsia, Orthis, Productus, &c., of Carboniferous species, in 1850. In the S. of Ireland, also, the lower carboniferous strata are slaty.

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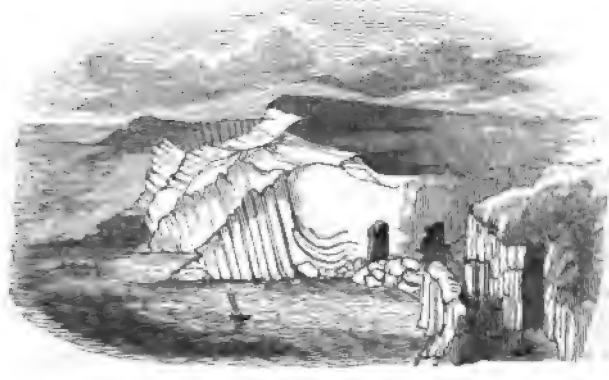
map, the Carboniferous group (*b* to *g*) may be stated to lie between the subjacent Old Red, *a*, and the red overlying Permian, *h*, thus:—

GENERAL RELATIONS OF THE CARBONIFEROUS ROCKS IN THE CENTRAL AND SOUTHERN PARTS OF ENGLAND. (See Sil. Syst. p. 465.)

a. Upper beds of the Old Red Sandstone (Devonian). *b*. Sandstone and lower limestone shale. *c*. Carboniferous limestone. *d*. Millstone grit. *e*. Coal and ironstone. *f*. Main coal-fields. *g*. Upper coal with a peculiar limestone. *h*. Red sandstone (base of Permian rocks, *here represented as conformable to the coal, but usually transgressive*).

As it is impracticable to treat in detail of the various component parts of the strictly carboniferous deposits in different British districts, a very slight sketch only of some of their striking peculiarities is attempted in the following pages.

Separated from the upper band of the Old Red Sandstone by beds of dark and party-coloured shale (*b* of the section), the mountain limestone, *c*, is the dominant rock of the lower division in the South of England. The massive nature of these calcareous strata and their vast downward development in Derbyshire, Yorkshire, and Northumberland, have been long well known to geologists. Of late years, attention has been directed to the still greater expansion of the middle and lower strata in Scotland, where so many beds of excellent coal and much valuable iron-ore are interstratified with various bands of the carboniferous limestone, of which hereafter.



CLIFFS OF CARBONIFEROUS LIMESTONE NEAR STACKPOLE.
(Sketched by Lady Murchison. From Sil. Syst. p. 382.)

Within the region, however, of the annexed map, this mountain or carboniferous limestone (2000 feet thick) is of simple and uniform

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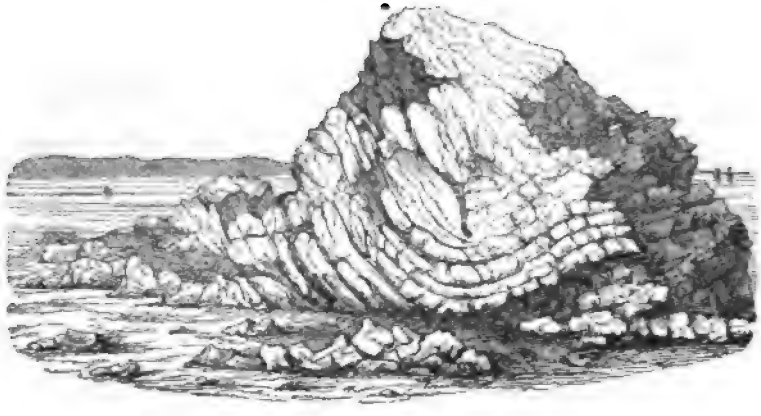
structure, and, as in Ireland, contains no coal-seams. When traced along the rim of the great South Wales coal-field, or from Caermarthen into Pembrokeshire, it is exhibited continuously, in bold coast cliffs, particularly in the promontory of Stackpole, where it is much contorted, as in these two sketches. The first of them represents the contortions of the rocks, with their numerous clefts (the master-joints of Sedgwick), which by the power of the waves have been so opened out as to form extensive caverns, as seen near Bull Slaughter Bay. The next is a view of one of the detached folds of the same limestone, known as Stackpole Rock. Though these cliffs seldom exceed 150 feet in height, yet, being precipitous and abrupt, they present a very rugged, wild, and picturesque barrier to the sea, when viewed from the shore; rivalling, indeed, the bold Northumbrian coast cliffs of the same age, as exhibited between the rivers Alne and Tweed.



STACKPOLE ROCK*.
(Sketched by Lady Murchison. From Sil. Syst. p. 370.)

Having alluded to the convolutions of the Pembrokeshire limestone, it is right to explain, that the violence of the movements which produced them, affected still more remarkably all the overlying carboniferous rocks of that region, and particularly the coal. Thus the latter, which is there nearly all in the state of culm† or anthracite, has been for the

* These striking cliffs are the property of my esteemed friend Earl Cawdor, whose chief residence, Stackpole Court, is situated on the carboniferous limestone, and whose other Welsh residence, Golden Grove (see the distant edifice in the sketch, p. 56) is on the Llandeilo flags of the Lower Silurian rocks.

† The variations in mineral character of the anthracitic or culm trough of North Devon (doubtless a mere extension of the Pembrokeshire coal-field) have been partially adverted to in the previous chapter. (See p. 292, and section, p. 294.) One thin course of black limestone with Posidonomyæ is, in N. Devon, the true representative of the great massive, white, calcareous cliffs of the opposite coast of Pembroke, and of the diversified North British series: so much for great mineral changes, within a few miles, of the same rocks in our own isles! (See p. 292 *et seq.*)

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most part shivered into small fragments, and is frequently accumulated in little troughs or hollows, the 'slashes' of the miners. Of the great lateral pressure and violent fractures to which the strata have been subjected, the following woodcut may convey some idea.

SLASH OF CULM, IN PEMBROKESHIRE. (From Sil. Syst. p. 377.)

a. Contorted culm strata with stone-coal, *a**. *b*. Fault. *c*. Slash of finely triturated culm between violently contorted strata, and probably upon a great line of fracture.

All these convolutions and fractures were produced long after the accumulation and solidification of the deposits under consideration.

Whilst the carboniferous limestone is separated, as before stated, from the Devonian, or Old Red, by shales (which in Pembrokeshire are in parts both sandy and calcareous), it is there, as in most other districts of England, surmounted by light-coloured sandstones of considerable thickness, which are known under the name of Millstone Grit. The following section of the general succession of the strata in Pembrokeshire exhibits, at one view, the whole order from the Silurian rocks up to the productive coal above the millstone grit.

GENERAL ORDER IN PEMBROKESHIRE.

To pass, however, from a diagram of the general order to a natural section, the English student may examine with ease and in a small compass, the Carboniferous series from its base upwards to the productive coal inclusive, on the south-east slope of the Titterstone Clee Hill in Shropshire†. Ascending from a depression in the Old Red Sandstone near Cleobury to the eastern summit of that hill, he will pass successively over the three divisions of limestone and shale, millstone grit, and productive coal; the whole being capped by basalt, which is seen to have been erupted through the entire series, and to have overflowed on the top of the hill.

† Any one who is desirous of understanding the peculiarities of this coal-field may refer to the 'Silurian System,' p. 113, where the proofs of the existence of a vertical mass of basalt, rising up through the strata, are explained, as well as the extraction of coal by shafts from beneath the overlying table of basalt.

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The Lower Carboniferous members, or the shale, limestone, and grit (*b*, *c*), are, however, of small dimensions in and around the Silurian region, when compared, I repeat, with their representatives in Derbyshire, the north of England, and particularly in Scotland, where they

SECTION ACROSS THE CORNBROOK COAL BASIN OF THE CLEE HILLS.
(From Sil. Syst. p. 113. pl. 30. f. 6.)

a. Upper beds of Old Red or Devonian. *b*. Carboniferous limestone and shale. *c*. Millstone grit. *d*. Coal-measures. * Eruptive basalt, which has risen through and overflowed the coal.

swell out into a vastly thicker series. In Pembrokeshire, also, these lower carboniferous rocks expand to some extent and begin to assume the Irish type. They contain fishes (Palæoniscus and Psammodus) with marine shells at their base. In the north-western parts of Lancashire and Yorkshire, also, as described by Prof. J. Phillips, those strata consist, in ascending order, of the Great Scar limestone, estimated to vary in thickness from 500 to 1000 feet; followed, in the west of Yorkshire, by considerable alternations of shale and limestone, called by Professor Phillips the 'Yoredale Series,' and considered by him to be about 1000 feet thick; while the whole is surmounted by 800 feet of millstone grit†.

Development of the Northumbrian and Scottish Coal.—Besides its grand protrusions of basalt and greenstone, the bold coast of Northumberland and South Berwickshire exhibits these lower carboniferous limestones opening out into different courses and interlaced by copious masses of schist and several coal-seams. One of the calcareous bands, near to the centre of the group, is especially characterized by the Posidonomya Becheri (Bronn). Now, it is to be specially noticed, that it is through this striking species (which occurs also in the *Calp* of Ireland) that the thin beds of black or culm limestone in Devonshire, wherein it also occurs, are known to be of this age (see section, p. 294). This fossil is, further, of frequent occurrence in the schists and 'kiesel-schiefer' of the Rhenish provinces of Prussia, both with and without limestone, and is therefore a good type of the lower carboniferous age. It was by such proofs, and by the order of the strata, that Professor Sedgwick and myself showed, how the Rhenish schists with Posidonomyæ were the exact equivalents of the British carboniferous or culm limestone of

† See the memoirs of Professor Sedgwick, 'On the General Structure of the Cumbrian Mountains,' and 'On the Carboniferous Chain from Penyghent to Kirkby Stephen' (Trans. Geol. Soc., n. s., vol. iv. pp. 47 *et seq.*); also Phillips, Geology of Yorkshire, vol. ii., a most valuable monograph of the native county of the distinguished author.

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Devon, and how the sandstone which overlies them (the 'Jüngere Grauwacke,' or 'Flötz-leerer Sandstein' of the Germans) is the representative of the British millstone grit *.

Ascending from the uppermost Old Red, occasionally a yellowish sandstone characterized by the Holoptychius Andersoni and Pterichthys hydrocephalus of Agassiz, the lowest carboniferous beds, as seen in the counties of Haddington, Edinburgh, and Fife, consist of a very thick series of sandstones and shale, laden with the remains of plants, and occasional courses of limestone, to the lower mass of which that sound geologist, Mr. Charles Maclaren †, assigned the general name of 'Calciferous Sandstones.' In the environs of the metropolis, the lowest carboniferous zone ranges from near Portobello, on the east, to Linlithgow, on the west; the city of Edinburgh being entirely built out of its excellent freestone. It also contains thin layers of coal, though the mineral is rarely of sufficient value to be worked. The upper portion of this lowest member, particularly in Edinburghshire and Fifeshire, exhibits those courses of limestone (one of the thickest masses being known at Burdie House), the beds of which are charged with numerous fossil fishes, such as Holoptychius Hibberti, Palæoniscus Robisoni, Pygopterus Bucklandi, Uronotus crenatus, Megalichthys Hibberti, &c. Some fossils of this band, including the shells called Unio (Anthracosia of King), with Cypris or Cythere, have been referred to freshwater origin; but, on the whole, the deposit may be viewed as one formed in brackish-water bays or estuaries, in which large and predaceous sauroid fishes prevailed.

The next zone, in ascending order, and in which lie the productive coal-fields of Scotland, is, on the contrary, one of purely marine character, in respect to its fossil-bearing limestones; since all these calcareous beds, which alternate with coal, shale, and sandstone, are charged with the sea-shells of the Mountain or Carboniferous Limestone. For, as all these limestones (of which the Government Surveyors, Messrs. Howell and Geikie ‡, have discovered eight distinct beds in Mid- and

* See Trans. Geol. Soc., n. s., vol. vi. p. 228 *et seq.*

† Geology of Fife and the Lothians, 1839.

‡ As Director-General of the Geological Survey of the British Isles, it is my duty to explain, that all the progress has been made in Scotland which is compatible with the limited amount of publication of the Ordnance maps. The boundaries, subdivisions, and details of the carboniferous masses, and their relations to Silurian, Old Red, and igneous rocks in the counties of Edinburgh, Haddington, and Fife, or around the Scottish metropolis, have already been defined upon the six-inch maps, and will soon be published in the usual one-inch scale. Again, whilst these pages are passing through the press, the Rev. T. Brown has transmitted to me a valuable detailed section along the south coast of Fife, in which Mr. Brown shows the vast thickness of the inferior series of sandstones and shale with eight calcareous courses and five beds of the ordinary carboniferous or Productus limestone, the whole being in great undulations, with many protrusions of igneous rock, and several thousand feet in thickness, as the Government Surveyors have also shown. He has also detected a remarkable bone-bed, containing Eurypterus and Holoptychius Portlockii, between the two calcareous zones above mentioned.

An able and luminous sketch of the

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East Lothian) are laden with well-known Producti, Bellerophons, Orthoceratites, and other Mountain Limestone types, the true geological horizon of the great Scottish coal-field is absolutely determined, being manifestly older than the chief productive overlying coal-fields of England.

A general conception of the productive Scottish coal-fields may be gleaned from an inspection of the section (p. 177) representing the order of the geological series in the western parts of Lanarkshire. There, in proceeding upwards from the Upper Silurian rocks and Old Red Sandstone, the succession is admirably exposed on the sides of the brooks which descend from the higher moorlands. In these ravines the student sees, exposed to day, the manner in which several bands of limestone, charged with Producti and various fossils, alternate with shales replete with plants and seams of coal, as well as with courses of the celebrated calcareous iron-ore known as the 'Black Band*.'

We have yet, however, to learn the precise place in the series, of the coal strata of parts of Ayrshire, which are extensively overlapped by a red sandstone and conglomerate supposed to be of Permian age. Some of these coal-beds, particularly those of Dumfriesshire, may prove to be of the age of the upper coal-fields of England.

Lower Carboniferous Rocks in Ireland.—In no portion of Europe, except Russia, are the Lower Carboniferous rocks more widely extended than in Ireland, and at the same time so little productive of coal. This is doubtless in some measure due to the fact, that by far the greater portion of the Irish series pertains to the lower carboniferous divisions, which, though it is in Scotland, as above stated, very rich in coal and iron, exhibits no such qualities in those parts of England which lie in the same parallels of latitude as the mass of the Irish rocks of this age. Exclusive of the strata that are separated as being of Old Red or Devonian age (see p. 302), the 'yellow sandstone' of Griffith, so defined, where it is interstratified with limestone and shale containing carboniferous fossils with Stigmariæ, as in Scotland, is the oldest member of the system. This is followed upwards by schists, which assume a slaty structure, particularly in the Cork district, and alternate with courses of limestone. The middle portion is composed of the great lower limestone, followed by the dark grey, earthy limestone, known under the name of 'Calp'; whilst the 'Upper Limestone' of the midland and

Scottish coal-fields is given in the compendious and useful work of Mr. D. Page, entitled 'Advanced Textbook of Geology,' wherein the student will find that the triple division of the Carboniferous system is well defined (p. 137).

* See the memoir 'On the Silurian and Lower Carboniferous Rocks of Lesmahago,' in the Journal of the Geological Society, vol. xii. p. 15, &c. Since the first edition of this work appeared, I visited these localities in Lesmahago parish, in company with Professor Ramsay, and under the guidance of Mr. Robert Slimon, Surgeon, of that place, to whom I have already alluded as the discoverer of the fossils of the transition strata between the Old Red Sandstone and Upper Silurian rocks of the same tract. The great mass of the Old Red is there wanting.

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southern districts of Ireland is covered by the 'Millstone Grit' with a little coal.

Reposing conformably upon the Red Sandstone described in the last chapter, this great succession of sandstone, limestone, and shale, the latter occasionally affected by a slaty cleavage, is seldom, indeed, seen in one clear and consecutive section. Undulating over very wide areas, it is usually much obscured by gravel, shingle, and clay. Even when the limestones form natural escarpments, they exhibit no seams of coal worthy of notice; as, for example, on the south bank of Lough Erne, and in the hills near Florence Court to the south of Enniskillen, where they exhibit a splendid succession and numerous fossils, including large Producti in the lower, and Posidonomyæ in the higher strata. In the Cork district, indeed (where the lower schists are so slaty and crystalline, that they might be mistaken for much older rocks), a little coal of slight value has been found—a very feeble representative of the great Scotch coal deposits of similar age.

The limestone series of Ireland is proved to be of exclusively marine origin, from the multitude of well-preserved fossils it contains; and of these Sir Richard Griffith (with the assistance of Professor M'Coy) has already prepared a description of about 500 species*, a considerable number of which are stated to be identical with those of the Devonian rocks, but altogether different from those of the Silurian system. These lower members of the system constitute, as before stated, by far the larger portion of all that is carboniferous in Ireland, and are surmounted (but very partially) by grits and sandstones, in which, at four localities (Kilkenny in the south, and Ballycastle, Dungannon, and Coal Island in the north), a few thin beds of coal are situated; but as they are of comparatively slight local value, and have no special bearing on the object of this work, I refrain from saying more respecting them†.

The Lower Carboniferous strata hitherto spoken of, or the sandstones, shales, limestones, and grits, are all over Europe and North America, for the most part of marine origin. The arenaceous and schistose lower strata have, indeed, strong mineral and zoological affinities to the upper portion of the underlying Devonian rocks, into which they graduate. On the whole, however, and notably in its great central masses, this lower division is distinguished from the Devonian by its chief animal remains,

* A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland, 1844.

† Having under consideration the enormous area occupied by the carboniferous strata of North America, Professor H. Rogers endeavours to reconcile the conflicting hypotheses respecting the origin of coal. (See Transactions American Assoc. Adv. of Science, 1842, p. 433.) He ingeniously applies the opinions of his brother, W. Rogers, and himself, respecting the influence of great paroxysmal earthquakes which affected the earth's crust in ancient periods, and suggests how the alternations of terrestrial and oceanic remains, to which attention has been called in this chapter, and particularly at p. 316 *et seq.*, can be best explained.

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including certain genera of fishes; and, above all, by the intermixture of infinitely more terrestrial plants than are known in the preceding epoch. With repeated evidences of thin seams of coal being intercalated with bands of limestone of exclusively marine or estuary character, it is indeed a fair inference, that much of the vegetable matter out of which such lower coal was formed had been often transported in large matted masses from the mouths of great rivers, or drifted from the shores of broad jungles, into the adjacent seas, and so became commingled with marine remains.

Upper Carboniferous or overlying productive Coal-fields.—When we examine the nature of the great overlying coal strata, an order of things is opened out to us to a great extent different from that which prevailed during the formation of the lower coal.

If, indeed, we turn to Germany and France, we see a general physical phenomenon sufficient to explain the change from marine to prevailing terrestrial conditions. In those countries the lower carboniferous strata had been dislocated and inclined before the upper coal deposits began to be accumulated on their edges, and hence we can apply to the latter a physical explanation of their method of formation which is quite inapplicable to the former. In short, the origin of coal in the younger of these accumulations may be very well accounted for by the depression of low woodlands and jungles beneath fresh water, followed by subsequent elevations and depressions—phenomena which can scarcely be admitted into our reasoning, so long as we refer to the submarine state of things which prevailed in the older Carboniferous era, many of the strata of which must have been accumulated under deep seas.

In Britain, however, there is no such abrupt severance in the middle of this natural series, and yet we there see the same changes from marine or estuary conditions to a terrestrial state, as in those regions which have undergone a great physical disturbance. Thus, in the thick, overlying coal-fields of England, whether in the South Welsh basin, or the Newcastle and Durham fields, we lose all traces of marine life, and can recognize only huge accumulations of lacustrine or fluviatile origin. In South Wales, where the upper coal-measures are estimated to attain the great thickness of 12,000 feet, and one hundred coal-beds are intercalated at various levels, we have undeniable evidence of successive terrestrial conditions—each of these coal-seams having immediately beneath it a band of sandy shale, called under-clay, and abounding in Stigmaria, or the *roots* of Sigillaria, one of the plants from which coal has been generated. For this important fact, science is chiefly indebted to Sir William Logan, who demonstrated that the under-clay of the miner had been the soil of a primeval marsh or jungle. (See also Mammatt's Geological Facts, &c. 1834, p. 73.)

The woodcut in the beginning of the chapter is intended to convey a

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general idea of the nature of the wet and swampy tracts in which the vegetation of this period flourished.

The comparative rarity of true dicotyledons or forest trees in this flora, due perhaps in part to the rapid decomposition of vegetable bodies in a moist intertropical climate*, is as remarkable as the extraordinary uniformity in the families of plants of which it was composed. These consisted chiefly, as before said, of Lepidodendra, Equisetaceæ, Asterophyllites, and Sigillariæ, with some curious extinct pine-trees, a few of which resembled the living Araucaria of Norfolk Island. As many of these are found in the roof of the coal, and sometimes even in the coal itself†, there can remain but little doubt, that, in most of these cases, the mineral resulted from the decomposition and fossilization of the plants which grew in extensive, marshy jungles. It may fairly be inferred, that this conversion of vegetables into coal took place at a period in the formation of the crust of the earth, when very different physical conditions prevailed, and when a warmer and more equable (though probably not a hot) climate pervaded our islands, as well as latitudes far to the north and south of them. The view which supposes many and successive subsidences of vast swampy jungles beneath the level of the waters best explains how the different vegetable masses became so covered by beds of sand and mud, as to form the sandstone and shale of such coal-fields. But this theory of oscillation, or of the subsidence *en masse* of ancient marshes and their probable re-elevation (with occasional sand-drifts), though good in such examples as those of the South Welsh and Newcastle coal-fields in England, as also of the large coal-fields in British North America, to which Sir C. Lyell has called attention‡, can scarcely have an application to those other seams of coal, which, as before mentioned, are interstratified with beds containing marine shells, the animals of which, such as Producti and Spirifers, must have lived in comparatively deep sea-water.

In such examples (and most of the older coal-beds come into the category) we may, on the contrary, endeavour to explain the facts by the supposition, that ancient streams like the present Mississippi and other large rivers, which flowed through groves on low lands and mud

* See Hawkshaw, Proc. Geol. Soc. vol. iii. p. 269. The reader will also do well to consult Prof. Lindley's notice of his experiments in decomposing vegetable bodies (see Lindley and Hutton's 'Fossil Flora of Great Britain,' vol. iii. pp. 1-12).

† Few persons, who are attentive observers of the fuel they consume, will have failed to detect the forms of plants in the coal itself. Göppert has, indeed, demonstrated, by microscopic examination (and Witham in part anticipated him, 'Observations on Fossil Vegetables,' 1833), that the vegetable fibres and tissues of all the families of the plants of this era are to be detected in the coal itself. In some layers all the plants are calamites, in others, ferns. (Quart. Journ. Geol. Soc. vol. v. part 2, Mem. p. 17.)

‡ See an excellent general sketch of the chief carboniferous deposits of Europe and America, with illustrations of the prevailing plants, in Lyell's Manual of Geology, 1851, 24th and 25th Chapters; and 5th edit. 1855. See also Ansted's 'Ancient World.'

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banks, transported great quantities of trees, leaves, and roots entangled in earth, and deposited them at the bottom of adjacent estuaries, or that these heaps of vegetable matter were carried as floating masses into the broad, open sea.

The coasts of Northumberland and Berwickshire, as well as the large tracts of Scotland already alluded to, exhibit fine proofs of such conditions. The coal-field of the Donetz in Southern Russia, *i. e.* between the Don and the Dnieper, was described by myself and associates as a striking example of the method by which these older carboniferous accumulations were brought about. There, as in Scotland, besides numerous beds of shale and sand with remains of plants, bands of limestone, charged with species of Productus, Spirifer, Bellerophon, Nautilus, and other marine shells and many corals, alternate several times with grits, sand, and shale charged with coal*, and filled with casts of terrestrial plants, including tree-ferns, Sigillariæ, Equisetites, Calamites, &c.

In geology, less indeed than in other sciences, can we ever hope to account for any result by one *modus operandi* only. For, nature has evidently worked out apparently similar phenomena, through distinct paths and by different processes; and of this no clearer proof can be given, than that coal was formed out of vegetables which were accumulated by at least the two methods above described,—the one subaqueous, the other terrestrial†.

General Observations on the Organic Remains.—In treating of the general physical relations of the Carboniferous rocks of the British Isles, and of some changes which they have undergone beyond the region of the annexed map, it has been stated, that in the South of Scotland, with the exception of the lowest strata, which are of estuarine origin, the greater part of the coal is interstratified with limestones containing the remains of marine animals. Most of the fossils, indeed, of those coal tracts, such as Nautilus, Productus, and Spirifer, with Crinoidea and Crustacea, unquestionably inhabited the sea.

Even in the lowest or estuarine zone of Scotland, large sauroid fishes, Megalichthys Hibberti, Agass., and Holoptychius Hibberti, Agass., were

* See 'Russia in Europe and the Ural Mountains,' vol. i. p. 89 *et seq.*, pl. 1, and large woodcut showing the vertical succession, p. 111.

† This view of the two modes of formation of coal, which I have long advocated (see 'Russia in Europe,' *loc. cit.*, and 'Siluria,' p. 280), has been adopted and well illustrated by Mr. D. Page in his 'Advanced Text-book,' p. 154; and it is fully treated on in the last edition of Mantell's 'Wonders of Geology' (1858). The inquirer who wishes to study the British fossil plants of this period must consult the 'Fossil Flora' of Lindley and Hutton. The same subject is still more developed by M. Adolphe Brongniart, who has given his views in an admirable sketch of the successive floras imbedded in the crust of the earth. The recent publications on the fossil plants of Germany, by Corda, Göppert, Unger, and Geinitz, are productions of high merit. In comparing these works with those on the coal plants of America, we find that, like the associated marine animals, the same species inhabited very distant regions, or had a wide range through many latitudes.

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associated with the shark-like fishes, Gyracanthus formosus, G. tuberculatus, Ctenacanthus, &c. In the great central limestones remains of these placoid fishes are also abundant. They are chiefly Cestracionts. Their teeth (Cladodus, Diplodus, &c.), or the hard bony palates of other genera,—Psammodus, Cochliodus, Helodus, together with the fin-defences above mentioned, are the only parts preserved; but these are sufficient to show, that they were very numerous as individuals, and consisted of many genera. These must be studied in the great work of Agassiz, or in the subsequent publications of Egerton and other authors*.

It is in the purely marine or central limestones of the Carboniferous epoch that the geologist takes his final leave of trilobites. Abounding in the Silurian era, these crustaceans had dwindled to a comparatively small number in the Devonian, whilst, in the Lower Carboniferous, the three genera, Phillipsia, Griffithides, and Brachymetopus, mark the last appearance of any individuals of this family in the ascending scale of primeval deposits. On the other hand, it is among the superior coal strata where trilobites became extinct, that we see in abundance the true Limulus, a genus of crustaceans which has lived on to the present day; the great King Crab of the Indian seas being the existing type†.

FOSSILS (78).

Limulus rotundatus, Prestwich.

From the Coalbrook Dale coal-field.

One example of this primeval Limulus is here given; it is a rarer species than the L. trilobitoides of Buckland‡. Limulus anthrax, Prestwich, also, is another rare form from Coalbrook Dale§. But not only are there crustacea of the Pœcilopod tribe (to which the King Crab belongs) in the coal, but other crustacea of a higher order. Both in

* See 'Palichthyologic Notes,' by Sir Philip de M. Grey Egerton, Bart., M.P., Quart. Journ. Geol. Soc. vol. iv. p. 302; vol. v. p. 329; vol. vi. p. 1, and Nos. 4, 5, in vol. ix. See also the Decades published in the Memoirs of the Geological Survey of England, in which that distinguished naturalist has published admirable descriptions of many fossil fishes. The collections of ichthyolites made by Sir P. Egerton and his associate, the Earl of Enniskillen, are, it is believed, unrivalled.

† A form closely allied to Limulus, but having the segments of the abdomen freely articulating with each other, occurs in the Ludlow rock. It is the Limuloides of M'Coy, and contains three or four species.

‡ See the Bridgewater Treatise, t. 46". fig. 3;—that very remarkable work of my eminent friend the late Dean of Westminster.

§ Trans. Geol. Soc. vol. v. pl. 41. f. 1–4.

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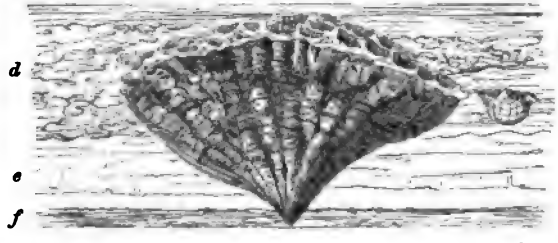
the S. Staffordshire coal-field and in that of Manchester, a peculiar form, probably of the Schizopod group, occurs, which Professor Huxley has described under the name of Pygocephalus Cooperi; and to this group, too, most probably belongs the carapace from Coalbrook Dale figured by Sir Charles Lyell, Man. Geol. 5th edit. p. 388, which was first referred to Apus by Milne-Edwards, and more lately considered a crustacean of the Shrimp family by Mr. Salter. Nor must we omit to mention the large Eurypteri found in the Glasgow coal-field, and first described by Hibbert in the Trans. Roy. Soc. Edinb. vol. xiii. These, with some others, an Amphipod? (Gampsonyx, or Uronectes fimbriatus, Jordan) from Germany, and numerous bivalve Entomostraca, chiefly of small size, show the fauna of the coal to have been rich in crustacean forms.

Here, also, we last meet with any large Orthocerata. Those scavengers of the ancient seas had now begun to diminish rapidly, and with them most of the genera of Cephalopods which have a simple form of air-chamber, their office being taken, in the Triassic and later Secondary strata, by other groups of Cephalopoda, such as Ceratites, Ammonites, &c., in which the air-chambers are minutely foliated at their edges.

The true characters of the very numerous genera and species of fossils which occur in this group must be studied in other works; but in support of the opinion, that the corals of the lower division often lived on the spot where they are found, a woodcut is here given of a gigantic specimen of Lithostrotion floriforme*, Sil. Syst., the lower parts of which

FOSSILS (79). CORAL OF THE MOUNTAIN LIMESTONE.



Lithostrotion floriforme, Fleming, in its natural position in the rock.

are rooted in the shale, *f*, whilst the superior portion is imbedded in a limestone, *e*, with a mass of red concretions, *d*, *d*. This coral, when in its native bed, appeared, therefore, to be precisely in its original position, and conveyed to me the impression that it had remained undisturbed beneath the sea, whilst fine red sand at one time, and mud with cal-

* My friend Mr. Lonsdale, who, as before stated, described all the corals in the 'Silurian System,' does not admit the generic word *Lonsdalia*, as applied to this form by M. Milne-Edwards; he, Mr. Lonsdale, having first defined and limited the genus Lithostrotion. See 'Russia and the Ural Mountains,' vol. i. p. 602, 1845; and Annals of Nat. Hist., Nov. 1851.

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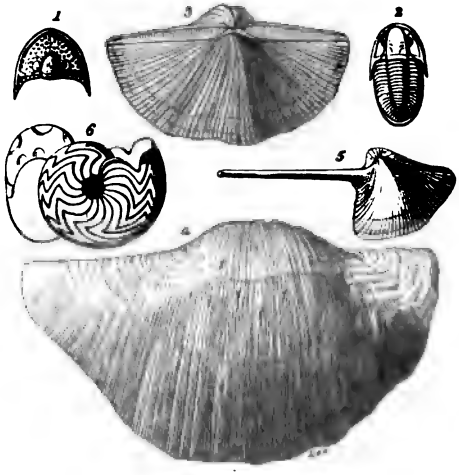
careous matter at another, were deposited around it. The small figure to the right of the woodcut represents the large shell, Productus hemisphæricus, which in nature is four inches broad, and shows by comparison the very great size of the coral, which has a width of two feet five inches*.

The large Producti are, however, of all its fossils, the most characteristic of the great limestone group, the same species being found in this rock through many degrees of latitude, in Europe, Asia, and America, and even in India and Australia. A few of these fossils are exhibited in the next woodcut.

FOSSILS (80). SOME FOSSILS OF THE CARBONIFEROUS LIMESTONE.



1. Brachymetopus Ouralicus, de Vern. 2. Phillipsia pustulata, Schloth. (P. gemmulifera, Phill.). 3. Spirifer striatus? Mart. sp. 4. Productus giganteus, Sow. 5. Pleurorhynchus aliformis, Sow. 6. Goniatites crenistria, Phillips.

But besides these numerous evidences of the presence of the sea, freshwater shells (Unionidæ) every now and then occur in thick layers, as we ascend in the series, and are among the most characteristic of the upper portions of the formation.

An estuarine intermixture is observable in coal-bearing strata of parts of Shropshire, Staffordshire, and Lancashire. It is well seen in the district of Coalbrook Dale, where remains even of insects allied to the Corydalis of America are found associated with marine and fluviatile shells and land plants. The figures in Foss. 81 represent this case of intermixture as formerly pointed out by myself. A fuller account, how-

* See Silurian System, p. 107. The coral is from Lilleshall, Shropshire, where the limestone rises out from beneath the coal.

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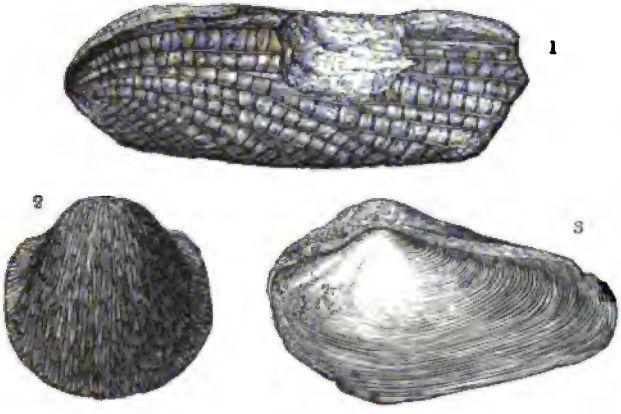
ever, is given of it by Mr. Prestwich, in his elaborate memoir on the strata and fossils of that district*.

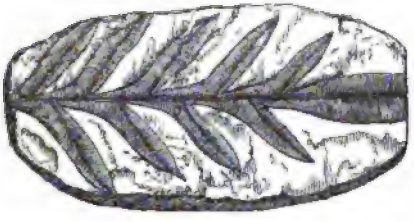
FOSSILS (81). INSECT AND SHELLS OF THE COAL.



1. Wing of Corydalis? Brongniarti, Mantell.
2. Productus scabriculus, Sowerby.
3. Unio acutus, Sow., Sil. Syst. p. 105. (Anthracosia acuta, King.)

Other probable examples of such associations, indicating the contiguity of land on which plants grew, and from which they were transported during long periods to marine or brackish water estuaries, are seen near

FOSSILS (82). FERN FROM COAL OF COALBROOK DALE.



Pecopteris lonchitica, Brongn. (From Sil. Syst. p. 105.)

Shrewsbury and other localities, among some of the younger coal strata, which at Manchester are seen to be of very great thickness. In the environs of Shrewsbury, small shells of the genus Cyclas (?) and valves of the minute crustacean Cypris (or possibly the marine genus Cythere) are commingled in the same limestone with a minute shell, originally termed Microconchus carbonarius, but now referred by naturalists to the marine or estuary genus Spirorbis†. The above-mentioned shells may indeed be also of marine origin.

* Trans. Geol. Soc. Lond. vol. v. p. 413. One of the plants, Pecopteris lonchitica (Brongn.), which is given in the lower woodcut, is associated in these tracts with forty or fifty species of terrestrial plants belonging to Calamitaceæ, Polypodiaceæ, and Lycopodiaceæ. Of these, the Stigmaria ficoides (considered to be the root of Sigillaria), Neuropteris cordata, Odontopteris obtusa, and the Pecopteris here figured, are perhaps the most common.

† Some of the coal sandstones in the

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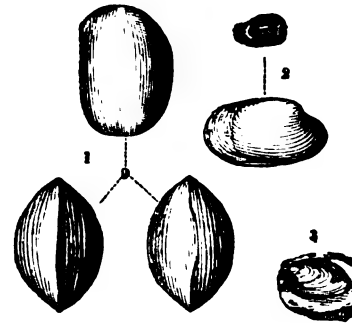
The following figures (Foss. 83, 84), formerly published in the 'Silu-

FOSSILS (83). UPPERMOST LIMESTONE OF THE COAL. (From Sil. Syst. p. 84.)

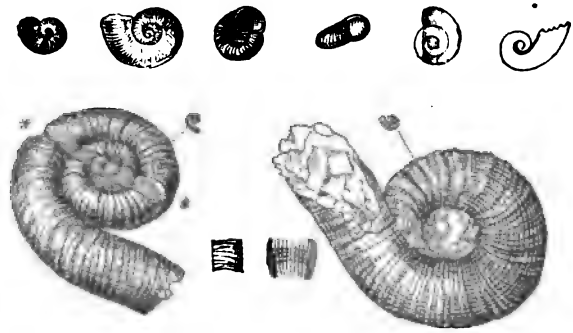


1. Cypris (or Cytheropsis?) inflata, natural size, and magnified 12 times. 2. Cyclas (or Edmondia?).

3. Modiola, from Ardwick, Manchester, in a somewhat similar band of limestone. (From Sil. Syst. p. 84.)

rian System,' explain more particularly the contents of this peculiar limestone of the coal strata.

FOSSILS (84). UPPERMOST LIMESTONE OF THE COAL. (From Sil. Syst. p. 84.)



Microconchus (now called Spirorbis) carbonarius, Sil. Syst. The real size is given in the minutest of these figures, whilst the upper figures are somewhat magnified, and the lower very greatly so. * *. The mark of attachment to some small cylindrical body.

In all such cases, and still more where the coal is intercalated, as before said, among purely marine animal remains, we must believe, that the vegetables from which it was formed were carried down into seas or estuaries fed by freshwater affluents.

Whilst researches in all parts of the world have produced only one

environs of Manchester exhibit on their surfaces the clearest indications of having been shore deposits; certain tracks being marked on them, of animals which must have crawled at ebb tides. Mr. Binney states also, that the shells of the above Spirorbis occur throughout the whole of the thick series of the Lancashire coal-field, and thus indicate the long-continued action of marine conditions. See a valuable paper 'On some Trails and Holes in the Carboniferous Strata, with Remarks on Microconchus carbonarius,' by Mr. E. W. Binney, Transactions of the Literary and Philosophical Society of Manchester, vol. x., 1851–52.

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small reptile from the uppermost Old Red or Devonian rocks, it was stated that the same strata afforded comparatively few land plants. The appearance, therefore, of land plants and air-breathing reptiles was, as far as our evidences go, nearly contemporaneous.

With the proofs in our possession of the large quantities of terrestrial vegetables which occur in the Carboniferous era now under consideration, accompanied as they are in numerous cases by river and lake shells, and in other instances by insects and Arachnida, it might be expected that reptiles would also be procured from them; and such has proved to be the case. The first discovery of this nature was made in the coal-field of Saarbrück in Rhenish Bavaria (a coal-field also rich in insects), wherein two species of Archegosaurus, Goldfuss, have been found,—a reptile which Hermann von Meyer supposes to be a connecting link between Batrachians and Lizards.

Since then, the footsteps of a large reptile allied to the Cheirotherium have been observed in the carboniferous strata of Pennsylvania; and Professor M'Coy detected in the Museum of Lord Enniskillen the remains of a small allied reptile from the British coal-fields, which Owen has described under the name of Parabatrachus Colei. The labyrinthodont Baphetes planiceps (Owen) was found in a coal-seam at Pictou, Nova Scotia. Sir C. Lyell has also communicated the still more interesting account of a discovery made by Mr. Dawson and himself, in the coal-field of South Joggins, in Nova Scotia*, of a reptile called Dendrerpeton Acadianum, which Owen and Wyman consider to belong to the perennibranchiate Batrachians. With this reptile were associated many land plants, and the shell of a mollusk, which is supposed to have been air-breathing: if this be so, it is the first true land-shell which has been found in strata of such high antiquity†. These discoveries afford us proofs of associations of organic remains which we might, indeed, have anticipated.

Even in our own islands, footmarks of Sauroid animals have been detected and described by Hugh Miller‡ from the coal-field south of Edinburgh; and again, whilst I write, the impressions of the feet of another sauroid? animal have been found in the coal-field of the Forest of Dean §.

According to Professor Owen, these last-mentioned footmarks (if the want of regularity will permit that term) might have been produced by the wriggling movements of a Salamandroid quadruped. They very much resemble the impressions called Steropezoon, Anomæpus, and Triænopus by Hitchcock; but "of these (Owen adds), no more definite idea is entertained than a vague one of their having been produced by a kind of great Newt-like reptile."

* Quart. Journ. Geol. Soc. vol. ix. p. 55.
† Ibid. vol. ix. p. 58.
‡ See 'Testimony of the Rocks,' p. 78.
§ This specimen is in the Museum of the Geological Society, and was sent to me by the Rev. Charles H. Bromby.

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In the earliest wide and general diffusion of a copious and peculiar vegetation above spoken of, we further recognize the prevalence of that equable temperature and similar conditions over various latitudes, which must, in my opinion, have also existed, to a great extent, in the preceding periods.

The specific identity, also, of many of the brachiopods of the marine or Lower Carboniferous rocks situated at enormous distances in latitude from one another (*e. g.* from the Arctic circle to within a few degrees of the Equator) is an additional and striking proof of the general uniformity of temperature and conditions during this epoch.

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CHAPTER XIII.

PERMIAN ROCKS.

CHANGES OF THE FORMER SURFACE.—ORIGIN OF THE TERM 'PERMIAN' AS APPLIED TO THE HIGHEST GROUP OF PRIMEVAL DEPOSITS.—THE PERMIAN ROCKS OF RUSSIA, GERMANY, AND ENGLAND.—THE ORGANIC REMAINS OF THE GROUP.

IN the two previous chapters, slight allusions only have been made to igneous or volcanic materials, ejected and spread out on the sea-bottom contemporaneously with the ordinary sedimentary deposits; for, during the Devonian and Carboniferous eras, such eruptions were not by any means so abundant in the British Isles as when the Silurian rocks, and especially their lower divisions, had been accumulated. (See p. 83, &c.)

The great upper coal-fields considered in the previous chapter were probably, in regions like Britain and America, evolved under conditions which geologists would consider comparatively quiescent. This is supposed to have been particularly the case with those coal-beds which were formed by repeated depressions of low lands beneath the waters, followed by elevation of the same into the atmosphere, and the consequent restoration of a terrestrial surface. The close, however, of that period was specially marked by convulsions and ruptures of the crust of the earth, which, from the physical evidences placed before us, must have extended over very distant regions. Whatever may have been the previous changes, it was then that the coal-strata and their antecedent formations were very generally broken up, and thrown, by grand upheavals, into separate basins, which were fractured by numberless powerful dislocations. The order of ancient sedimentary succession was thus very widely, though not universally, interrupted; and all the strata previously spoken of were so disturbed, as to produce a prevalent break or discordance between the carboniferous deposits with subjacent formations and those which succeeded to them.

This disturbance was not, however, general; since there are exceptional tracts in which the carboniferous and overlying Permian

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deposits are, it is said, in apparently conformable relations to each other.

The general effect of the great disseverment alluded to, in determining a former outline of the earth, is obvious; for, whilst the Silurian, Devonian, and Carboniferous rocks were at that period so heaved up as to constitute portions of mountain chains, the strata which we are now considering have been for the most part spread out in lesser elevations; constituting countries with a lower level. Notwithstanding, however, these physical changes, the animals and plants of the Permian era, though chiefly of new species, are generically connected with those of the preceding or Carboniferous epoch; whilst they are wholly dissimilar to those of the next succeeding period, the Trias.

The strata which were accumulated immediately after the great deposits of coal, have, in England, been severally termed Lower New Red Sandstone, Marl Slate, Magnesian Limestone, &c. Similar rocks have been long known in Germany under the names of Rothtodt-liegende, Kupfer-schiefer, Zechstein, &c. To these I have united an inferior portion of what had been commonly classed with the Bunter Sandstein. Having become satisfied that all these strata, so different in mineral character, constituted one natural group only, which must be distinguished from, though connected with, the carboniferous series beneath, and which, on account of its organic contents, must be entirely separated from all formations above, I proposed in 1841* to my associates, de Verneuil and von Keyserling, that the group should receive the name of Permian, a term taken from an extensive region which composed the ancient kingdom of Permia. To that vast country the illustrious Humboldt particularly called the attention of de Verneuil and myself when we were about to revisit Russia; and there we found that all the characteristic features of an independent assemblage were developed on a very grand scale.

After two explorations of Russia with my companions, I re-examined (1844) those portions of Germany where the Zechstein and its associated strata, underlying as well as overlying, are best

* The term was first proposed in a letter addressed by me at Moscow to the venerable and accomplished Russian paleontologist Dr. Fischer, October 1841. See Bronn and Leonhard, Jahrbuch, 1841, and Phil. Mag. vol. xix. p. 417.

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displayed; and, by placing these in parallel with the Russian and English rocks, my views were confirmed, and thus all the deposits above mentioned were included by me under the term 'Permian.'

The value of this euphonial name, for a series of strata composing one natural group, soon became so obvious, that, although proposed only in 1841, it was soon adopted by nearly all geologists of different nations.

In Germany, where the Roth-todt-liegende, Kupfer-schiefer, and Zechstein had long had their head-quarters, and where their characters had been described by numerous geologists, from the days of Werner and Schlotheim to those of the great geologist Leopold von Buch, whose loss we deplore, these rocks have been recognized in the works of Naumann of Leipsic, of Geinitz and Gutbier of Dresden, and of Göppert of Breslau, as the 'Permische System*.'

In France, the late M. Alcide d'Orbigny, in his systematic work on Paleontology†, and other authors, have given currency to a name, which would, indeed, have had little or no value without the close paleontological comparisons of my colleagues, de Verneuil and von Keyserling, as worked out with me in the easternmost regions of Russia in Europe.

In the north of England, the different deposits which are now united in a group, were admirably described by Sedgwick‡, who clearly showed their relations to the German rocks of like age. Subsequently, the organic remains of the Magnesian Limestone have been illustrated by King§, Howse‖, Kirkby¶, and other authors, under the term Permian; and the word has been used for some time in the construction of geological maps, and by Ormerod**, Binney††, Harkness‡‡, and other geologists in local descriptions.

As many persons may not have access to the large volumes on the geology of Russia, in which a full description is given of the

* See Geinitz and Gutbier, 'Permische System in Sachsen,' 1848. Dresden and Leipsic.

† See Cours élémentaire de Pal. et Géol. Strat., par Alcide d'Orbigny, vol. ii. p. 370.

‡ Trans. Geol. Soc. vol. ii., n. s., p. 37 *et seq.* My friend Professor Phillips had the merit of having first suggested that, on account of its fossils, the 'Magnesian Limestone' of England should be classed with the paleozoic rocks. Treatise on Geology, p. 189.

§ Monograph Palæont. Soc. 1856; Ann. Nat. Hist. 2 ser. vol. xvii.; and Journal Geol. Soc. Dublin, vol. vii.

‖ Ann. Nat. Hist. 2ser. vol. xix. p. 33 &c.

¶ Journal of the Geological Society, vol. xiii. p. 213.

** Journ. Geol. Soc. vol. vii. p. 268.

†† Mem. Lit. & Phil. Soc. Manchester, vols. xii. and xiv.; Quart. Journ. Geol. Soc. vol. xii. p. 138.

‡‡ Quart. Journ. Geol. Soc. vol. xii. p. 267.

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leading characters of the group in that empire, and as I wish to put the reader into possession of the reasons for the adoption of the name Permian, a few passages from the writings of myself and colleagues are here reproduced. By the first of these extracts it will be perceived, that, in describing the whole structure of Russia, we began, as on the present occasion, with the lowest rocks in which any traces of life could be detected.

"Having worked our way upwards through Silurian, Devonian, and Carboniferous rocks, we have now to describe the next succeeding natural group. Spread out over a larger surface than any others in Russia, the rocks in question, *with certain overlying red deposits*, which we cannot separate from them, occupy the greater part of the Governments of Perm, Orenburg, Kazan, Nijni Novogorod, Yaroslavl, Kostroma, Viatka, and Vologda, a region more than twice the size of the whole kingdom of France!"*

After showing to what an extent opinions varied respecting the age of these Russian deposits, most authors referring them to the New Red Sandstone or Trias, others to the Carboniferous era, it was next observed†:—

"Such was the state of the question when we entered upon the survey of Russia. To arrive, therefore, at a sound conclusion respecting the age of these rocks, it became essential to traverse, as far as possible, the countries over which they extended, and compare the phenomena which had led to such contradictory opinions. The result has been, that, though these deposits are of very varied mineral aspect, and consist of grits, sandstones, marls, conglomerates, and limestone, sometimes enclosing great masses of gypsum and rock-salt, and are also much impregnated with copper, and occasionally with sulphur, *yet the whole group is characterized by one type only of animal and vegetable life.*

"Convincing ourselves, in the field, that these strata were connected by their organic remains with the carboniferous rocks on the one hand, and were independent of the Trias on the other, we ventured to designate them by a geographical term, derived from the ancient kingdom of Perm, within and around whose precincts the necessary evidences had been obtained.

"With the highest respect for the labours of German geologists upon the Zechstein, and for the researches of those authors who have placed the Magnesian Limestone of England on the same parallel, we are convinced, that neither in Germany nor in Great Britain do the same accumulative proofs exist, to establish the independence of a geological system. If mineral characters be appealed to, no German writer will contend, that the thin course of 'Kupfer-schiefer' is of like importance with the numerous strata which in Russia constitute many bands of various structure; rendering, in fact, the Zechstein itself a mere subordinate member of a vast cupriferous series. Subordinate, however, as it is in some tracts of Russia, the Zechstein is so magnificently displayed in others, in masses of both limestone and gypsum, that it more than rivals the finest sections of that deposit, whether to the south of the Harz, or in Thuringia. We object, however, to a lithological name, hitherto reserved for one portion only of a complicated series; and, as the Germans have never proposed a single term for

* Russia in Europe, vol. i. p. 137. † Russia in Europe, p. 138.

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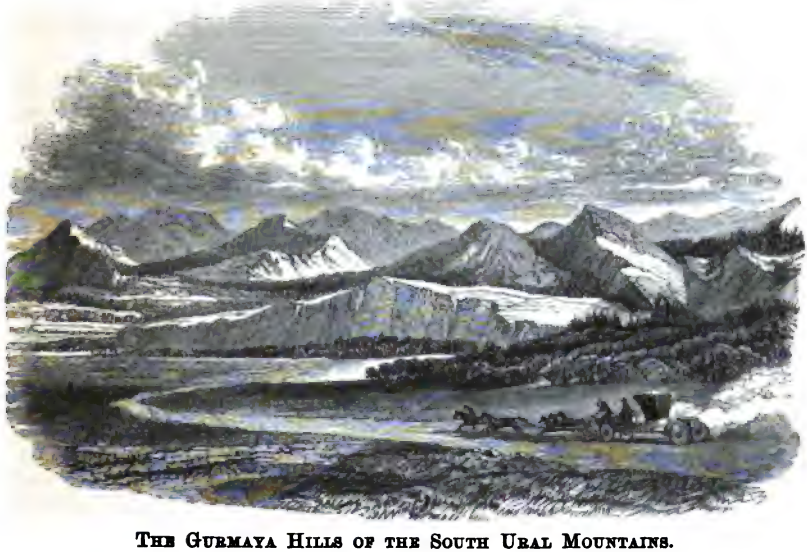
the whole group, which is based upon the Roth-todt-liegende, and surmounted by the Trias*, we have done so, simply because we first found in Russia the requisite union of proofs."

Occupying the enormous area before mentioned, the Permian deposits of Russia are flanked and underlaid on the west, east, and north, by upper members of the carboniferous rocks, but with little or no coal. These Permian strata of Russia seldom offer a mineral succession similar to that of formations of the same age in Western Europe; and in different tracts of the vast region explored, they exhibit, as explained in the preceding quotation, many variations in their mineral and organic contents, as well as in the relative position of the component masses. In some places, as on the river Kama, near its junction with the Volga, cupriferous red grits with plants underlie the chief limestone, and are succeeded by marls; but along the eastern limits of the group where it is flanked by the Ural Mountains, gypseous limestones seem to form the base, followed upwards by the red copper grits, sands, marls, and pebble-beds, which extend on all sides around the city of Perm. On the whole, indeed, whether we appealed to the sections on the banks of the great Dwina, above Archangel, or to the western flank of the Ural Mountains, or to the banks of the Lower Volga, near Kazan,



THE GURMAYA HILLS OF THE SOUTH URAL MOUNTAINS.

As seen from the Steppes of Orenburg. (From Russia in Europe, vol. i. p. 450.)

localities at vast distances from each other, we found that the limestones, of which there are several bands, often interstratified with much gypsum, prevailed towards the base of the Russian deposits.

In some parts of the region salt springs occur. These may, doubtless, rise

* The expression in the original should read thus: "for the whole group *which includes the Roth-todt-liegende, and is surmounted by the Trias*," &c.

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from solid bodies of salt in older paleozoic rocks, since the mineral is known to occur in the Old Red Sandstone of Livonia, or the Devonian of Western Russia; but in the steppes south of Orenburg, the masses of rock-salt rise to the surface, and are certainly subordinate to true Permian red deposits*. These salt beds range up to the base of the older paleozoic and crystalline masses of the South Ural Mountains to the east of Orenburg, the strata of Permian age being visible only in the low wooded slopes at the foot of the rocky chain, as represented in the preceding vignette.

Along certain portions of the west flank of the same chain, the Permian strata occur in almost apparent conformity to the carboniferous rocks. There they have manifestly undergone a movement impressed on them by great forces, directed from north to south, or parallel to the Ural Mountains; all the strata, whether carboniferous or Permian, having been raised up and thrown off sharply to the west†. From the Gurmaya Hills on the east to the Hill of Girialskaya on the west, the following succession is exhibited in ascending order in proceeding from the Silurian and Devonian rocks of the Ural chain:—Carboniferous limestone with the usual large Producti and other fossils, passing upwards into carboniferous flags, with slight traces only of coal. These rocks are followed by the Permian group, consisting of—1. Sandstones and grits—limestones in various courses with fossils of the Zechstein of Germany, associated with marls, gypsum, &c. 2. Red sands, with copper ores and many plants. 3. Conglomerate and sandstone, with plants and fossil reptiles.

At the Imperial baths of Sergiefsk, and on the banks of the river Sok, a tributary of the Lower Volga, magnesian limestone and marl contain gypsum, copper ore, native sulphur, with sulphureous and asphaltic springs in the middle masses, whilst other marlstones and white limestones constitute the summit. A considerable volume of gaseous, sulphureous water, which forms a large pool, issues from these rocks. (See diagram, 'Russia in Europe,' &c., vol. i. p. 158.)

Near Kazan, about 150 miles to the north of Sergiefsk, huge masses of gypsum ‡ (*a*), rising high above the level of the river Volga, are surmounted by limestone cliffs with Zechstein fossils (*b*), and the latter by red, green, and white marls (*c*), as here represented.

PERMIAN DEPOSITS NEAR KAZAN. (From 'Russia in Europe,' p. 162.)

a. Thick deposits of gypsum. *b*. Limestone with well-known Zechstein fossils. *c*. Red and green shelly marls, with Zechstein types.

On the contrary, in the central tracts between the Ural Mountains and the Volga, as on the Dioma and Kidash, tributaries of the great river Kama, the limestone, which in some tracts assumes a definite horizon, and is underlaid by coarse grits, is repeated at various levels in a succession of beds, interlaminated

* 'Russia in Europe,' &c., vol. i. p. 184.

† See section, 'Russia in Europe,' vol. i. p. 146, and 'Siluria,' 1st ed. p. 296.

‡ Cliffs of white gypsum, subordinate to the Permian rocks, are still more conspicuous on the banks of the Dwina S. of Archangel, where they form white cliffs for many miles, and again near Pinega, where myself and companions examined them in the year 1840.

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with sandstones, as well as yellow, white, and greenish marls, occasionally containing plants, also small seams of impure coal,—the whole being surmounted by red grits and conglomerates, with copper ore.

Now, the calcareous and gypseous deposits which interlace this series are throughout characterized by an analogous group of fossils, and even by some of the same species, as the Zechstein of Germany and the Magnesian Limestone of England; whilst the beds of copper grit, with the greatest part of the red conglomerates, which in the vast undisturbed region of Permia are *uppermost*, contain bones of a genus of reptiles which in Germany occurs in the copper slate *beneath* that limestone. Plants also, which are generically allied to the old Carboniferous flora, are of frequent occurrence in the governments of Perm, Orenburg, and Kazan, where they often lie in red sands and marls above all the limestones. Several indeed of these vegetables are identical with species described by Colonel Gutbier from the argillaceous beds of Zwickau in Saxony, belonging to the Roth-liegende beneath the Zechstein!, and Göppert has recently generalized the truth of this datum.

The exploration of this diversified Permian group of Russia, therefore, taught geologists not to dwell on the local mineral distinctions of Central or Western Europe, but to look to the wide spread of certain fossil remains, which, in vastly distant countries, occupy the same general horizon, though in different subdivisions of a group which clearly lies between the carboniferous rocks beneath, and all those overlying strata which are called secondary or mesozoic.

The survey further proved, by the extension of some of these fossils upwards, into red and green marls and sands far above the chief bands of limestone with well-known Zechstein fossils, that the Zechstein could no longer be properly considered the summit of this natural group. Let us now, therefore, consider the natural features and characters of the group in Germany.

Permian Rocks of Germany.—Before the publication of the work entitled 'Russia and the Ural Mountains,' above referred to, and three years after the word Permian had been proposed by myself, I re-examined those tracts of Germany, where rocks of this age are best developed, and had been long known through the writings of native geologists. Having since explored these lands upon three different occasions, during the first two of which I was accompanied by Professor Morris, and in the last by Mr. Rupert Jones, a condensed view, with some additional illustrations of the development of this natural group in Germany, is offered.

In the early days of our science, when Werner and his contemporaries clearly distinguished the different strata now united as the Permian group, it was natural that geologists should have adopted the names applied to these rocks by the miners of Saxony. The extraction of copper from a widely persistent but thin course of dark-coloured cupriferous schist, necessarily led the native workmen to assign certain names to the strata above and below the money-making band. Hence, the overlying red variegated sandstones being generally named 'Bunter,' or variegated sandstone, the limestone beneath this, and immediately above the copper slate, was termed 'Zechstein*;' the whitish and

* In a letter to myself, Leopold von Buch suggested, that the word Zechstein was probably derived from the Italian Zecchino, or Sequin, formerly a well-known coin in Germany, because this calcareous rock was the cover, which, being pierced, led to the bed of ore from which the miner derived his profit.

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grey pebbly beds subjacent to this metalliferous layer, and in which a little copper ore is also occasionally diffused, were designated 'Weiss-liegende;' and the great underlying mass of red conglomerates and sandstones, in which no trace of ore was detectable, received the expressive name of 'Roth-todt-liegende,' or the Red dead underlier. These names having remained attached to such rocks, it is far from my wish to disturb any one of them. On the contrary, in proposing the term Permian I wished simply to show, that they constitute one natural group terminating the paleozoic series, as seen in the region of Permia. This group, distinct from the coal-formation beneath, has for its base the Roth-todt-liegende, and for its summit the *lowest* member only of the great deposit of red and variegated sandstone, known in Germany as the Bunter Sandstein. This view, which I applied to the German succession after my last exploration of Russia in 1844, was the natural result of the similarity of the fauna and flora of this age in both countries.

As there is no portion of northern and central Germany in which the Permian group is more obviously separated from all underlying and overlying strata than in the tracts which flank the Thüringerwald, let us first consider its relations in those interesting districts.

Ranging from S.W. to N.E., the chain of the Thüringerwald is mainly composed in the former direction of those Silurian, Devonian, and Lower Carboniferous rocks which were formerly merged under the term 'Grauwacke,' and the relations of which will be explained in a subsequent chapter. Towards its north-eastern termination the nucleus of the range consists of crystalline schists pierced by granitic rocks and greenstone, as well as by porphyries, which throw off on both the south-western and north-eastern faces strata composing the Permian group. In proceeding from the S.W. to the N.E., or along the axis of the chain, the observer finds that he is travelling along a ridge chiefly occupied by porphyries, both black and red; the latter much predominating, and constituting the highest watershed of the wild woodlands known as the Renn-steig.

On either side of this central axis there are valleys, both longitudinal and transverse, forming deep indentations in the chain itself, in some of which there are exceptional outcrops of grey- and dark-coloured schistose beds, occasionally containing a few fossil plants, and in rare localities some beds of coal. These strata, differing considerably in mineral character from the Lower Carboniferous strata which have been raised up with the Devonian and Silurian rocks of the S. Thüringerwald, manifestly belong to the so-called Upper Coal of Germany. Such coal is most developed at the southern end of the Thüringerwald, where several beds of it have been reached by shafts which pass through vast thicknesses of overlying Roth-liegende. Advancing to the N.W., these deposits, detected at but few spots, have been found to contain coal only in the valleys west of Ilmenau, where, in the vicinity of certain eruptive rocks, the coal-beds are brought near to the surface.

The object in here alluding to these carboniferous strata, whether productive of fuel or not, is simply to point out, that, wherever they can be observed, they are here, as in other parts of Germany, transgressive to the overlying Roth-liegende. Whilst the former, judging from their fine lamination and imbedded fossil plants, resulted from tranquil deposition under water, the latter was formed during a period of great disturbance of the surface, accompanied by the extrusion of much igneous matter, and the powerful aqueous translation of many broken

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materials of pre-existing rocks. It is by the unmistakeable signs of such causation, that the basement strata of the Permian group are so vividly characterized, and by which they differ so essentially from those which preceded them.

In truth, various rocks of igneous origin have penetrated the Thüringerwald from a very early period; but it is only on ascending to the Roth-liegende that we are surrounded with porphyry, so that, as well laid down on the map of Credner, the northern part of the chain is seen to be, to a great extent, occupied by red porphyries which rise to the highest central summits, such as the Inselsberg and Schnee Kopf, the latter 3300 feet above the sea. It was, therefore, in this, the earlier part of the Permian era, that these grand protrusions or eruptions took place from S.E. to N.W., which obscured the ancient physical direction of the slaty rocks that trend from N.E. to S.W., and determined the axis or watershed of the ridge to be from S.E. to N.W., or at right angles to the strike of the slaty ridges.

The porphyries which ushered in a new series of deposits, are immediately flanked on either side of the Thüringerwald by the Permian group, which is interposed between the older rocks and the tranquilly deposited Trias. Now, at the north end of the Thüringerwald, where all such older rocks subside, as at and near the town of Eisenach, the core of the chain is composed exclusively of a splendid development of Roth-liegende, succeeded on either side by all the other members of the Permian group; the whole being symmetrically united. Here, in the deep valleys excavated in the Roth-liegende, the tourist meets with picturesque cliffs amidst a luxuriant foliage; and here it is that the geologist is specially invited, with the map of Credner, and the new work of Senft in hand, to study the characters of the lowest member of Permian deposits, which, in this neighbourhood, is expanded to the vast dimensions of at least 4000 feet.

This fact has been ascertained by boring through the lowest visible portions of this great accumulation in search of coal to the depth of 2600 feet of nearly horizontal strata, and by adding to the subjacent red sandstone, shale, and pebble-beds the thickness of the overlying deposits which are exposed in this hilly tract.

Fragments of the silicified plants and stems of Araucarites were found in the lowest strata which were bored through, similar to those which will presently be spoken of as occurring in the escarpments of the Kyfhauser, to the south of the Harz.

The reader will therefore understand, that, thick as the Roth-liegende appears to be in the accompanying woodcut, which I prepared last summer, after re-examining the tract in company with my able instructor Professor Senft of Eisenach, and Mr. R. Jones, it is the upper portion only of that deposit which is exposed. All the ascending order from it to the superjacent Permian rocks has now, by the recent cutting of the Frankfort Railroad, been as clearly laid open to the W.S.W., as it was previously on the eastern or opposite side of Eisenach. The reader who inspects this section will, therefore, have a good idea of the development of the Permian rocks of Northern Germany, with the exception of the lowest beds of the Roth-liegende.

a. At the north-eastern extremity of the Thüringerwald, the mass of red rock, *a* in the section, is seen to be covered by about 1400 feet of strata of red brecciated conglomerates, sandstones, and shale, terminating upwards in the light-coloured

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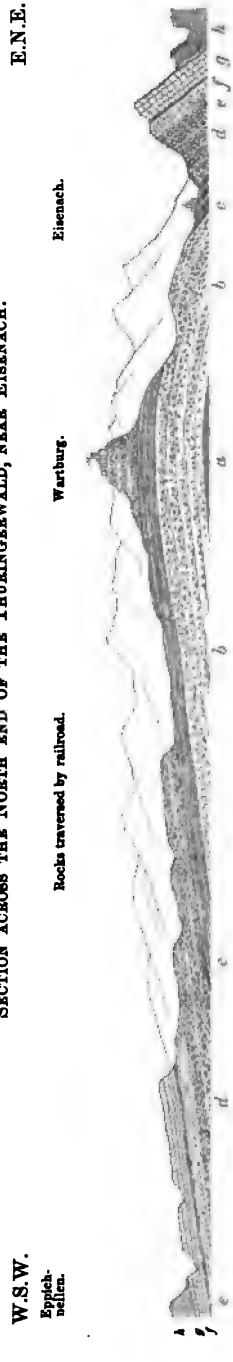

SECTION ACROSS THE NORTH END OF THE THÜRINGERWALD, NEAR EISENACH.

or whitish conglomerate which supports the Kupfer-schiefer and Zechstein. These bands, which are well exposed on the sides of the steep hills on either flank of the valley of Eisenach, and under the lofty hill on which stands the old Castle of Wartburg, celebrated as the residence of Luther, have been thus named by Professor Senft in ascending order.

b. Quartz conglomerate. This is truly a breccia composed of angular fragments, chiefly of quartz in a red matrix, but with some fragments of mica schist, slaty rocks, old porphyries, &c. This rock, though extensively denuded in the valley of Eisenach, rises to the west of the town into peaked and turreted masses having a thickness of 600 feet. It is well to remark here, that this, as well as the other so-called conglomerates of this age in many parts of Germany, are essentially angular breccias, which could not have been formed by the rolling action of waves on a shore, but must have been tumultuously and suddenly heaped together.

c. Dark red shale and sandstone, 250 feet. These beds, on the contrary, mark a period of quiescence, when the finely triturated sand and mud were accumulated.

d. Granite conglomerate, also an angular breccia; chiefly distinguished by containing fragments of a granite now unknown in the Thüringerwald, but resembling a rock still visible in the Harz. This breccia, with interlaminated bands of deep red sandy shale, supports the Castle of Wartburg*.

Folding over to the west, this last-mentioned rock has recently been tunneled through in making the new railroad to Frankfort, and is ascertained to have a thickness of about 500 feet.

Now, whether we follow these rocks to the west or to the east, we find, that the uppermost portion of the granitic brecciated conglomerate, *d*, as indicated in the section, graduates upwards into, and is succeeded by, another conglomerate, *e*, of a light grey colour, and therefore called locally the 'Grau-liegende†,' by Senft. This is the 'Weiss-liegende' of most German authors, and lies immediately beneath the Kupfer-schiefer. Mineralogically, it is

* This is the castle in which the great Protestant reformer, Luther, was secluded by the Elector of Saxony.

† The employment of this term, 'Grau-liegende,' is unfortunate; for Geinitz applies it, as we shall presently see, to the lowest member of the deposit near Dresden. 'Weiss-liegende' is the usual term.

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perfectly united with the subjacent Roth-liegende and with the overlying copper-slate, *f*, by the diffusion through all the junction beds of slightly cupriferous green earth. Again, in ascending still higher, an equally clear transition into the overlying limestone is seen by the conglomerate beds becoming somewhat calcareous and cupriferous; whilst in other parts of Germany, as near Gera, fossils even of the Zechstein have been found in this conglomerate stratum subjacent to the Kupfer-schiefer. Then follows the thin black course of the Kupfer-schiefer, *f*, with its numerous and well-known fossil fishes*, which is succeeded by the thick-bedded Zechstein, *g*, and its overlying members, which are dolomitic; these being covered by thin layers of fetid limestone, the 'stinkstein' of the Germans. In other sections on the sides of the Thüringerwald, gypsum occurs, and occasionally in large masses in this upper limb of the limestone, as at Rheinhardts Brunnen on the east, and again near Liebenstein on the west; but on either side of Eisenach the dolomite is simply succeeded by thin-bedded upper courses of fetid limestone or stinkstein.

Here, however, as indeed everywhere in this region of Germany, the highest calcareous layers of the Zechstein are conformably overlaid by red shale and sandstone, somewhat calcareous in some of its beds, and passing upwards into flaggy red sandstone. This last-mentioned rock has hitherto been classed by native geologists with the overlying Bunter Sandstein, into which it passes. As, however, it forms the natural capping of the Zechstein, I have united it with that rock; the more so, as throughout large regions of Russia, it is in marls, sandstones, and conglomerates, lying *above* limestones with Zechstein fossils, that plants and Protorosauri are found, which are identical with species from the Roth-liegende of Germany *beneath* the limestone.

In addition to the proofs drawn from the environs of Eisenach†, many other sections precisely similar might be cited from either flank of the Thüringerwald, the details of which are given elsewhere. For, whether we refer to the eastern side of the northern portion of the chain at Schmerbach, Kabarz, or Seebach, or to the western side at Kupfersuhl, Glücksbrunn, and Marksuhl, the subdivisions of the Permian group are seen to be naturally united‡.

A similar order is observable in the undulating region which extends north-westwards from Reichelsdorf to the banks of the Fulda. Whilst the Kupfer-schiefer of the tract around Reichelsdorf has afforded numerous fossil fishes and other remains, it is on the right bank of the Fulda, between Rotheburg and Altmorschen, on the north side of the railroad leading to Cassel, that the clearest evidences are afforded of that transition from the Zechstein upwards into overlying sandstones on which I lay so much stress. There, the Zechstein is observed to form the central mass of the red hills, having in its higher part large masses of gypsum, more or less amorphous, which are capped by thin layers of fetid

* In the summer of last year, and before I paid my last visit to the environs of Eisenach, Mr. Howse had examined the tract in company with Professor Senft, and had detected in the Kupfer-schiefer, near Eppichnellen, a splendid specimen of a fossil fish.

† The explorer who has only a few hours at his disposal should walk up the high ground called Göppels Hüppe, S.E. of Eisenach, and there see how conformably the Zechstein is capped by the red 'Sand-schiefer' (see opposite section).

‡ For detailed illustrations of this order of the Permian rocks on the flanks of the Thüringerwald, see the transverse sections, pl. 3, which accompany M. Credner's Geological Map. Also the memoir by myself and Professor Morris, Quart. Journ. Geol. Soc. vol. xi. p. 424, with sections.

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limestone. The latter, parting with their calcareous matter in the superior layers, gradually pass up into red schistose and flagstone layers, and red and green marls; the whole covered by whitish-coloured pebbly sandstones. All this succession is often clearly exposed in one and the same hill, the strata being slightly inclined to the north.

A like succession is further traceable along the eastern face of the older schistose rocks (chiefly Devonian), which range from Marsberg and Arolsen by Sachsenhausen, and are even traceable at Marburg. Reappearing in the broad Permian tracts of the Wetterau, the same relations are prolonged to the environs of Hanau, east of Frankfort on the Maine *.

In all these countries, and throughout the region between the Thüringerwald and the Harz, there is, I maintain, no difficulty whatever in separating the red rocks which form the natural cover of the Zechstein from the great formation of Bunter Sandstein. The latter is naturally connected with the Muschelkalk, and forms the true base of the Trias. On this point it may further be observed, that in no part of Germany has there been detected in the sandstone forming the cap of the Zechstein a fossil which can be referred to a mesozoic age; whilst the only plant found in that red rock is the Calamites arenarius (Ad. Brongn.), which is manifestly a paleozoic form.

Reverting to the great inferior member of the Permian group, attention should be specially paid to its extraordinary variation in thickness—a characteristic feature, indeed, of all conglomerates. Thus, whilst, as above cited, it has a thickness of 4000 feet at Eisenach, yet, near Schmerbach and Seebach, a few miles only west of that place, where porphyries rise up behind it, no more than 100 or 200 feet of this deposit are exposed; and yet we there see quite as clear and conformable a transition from the red rock beneath into the 'Weiss-liegende' above it, and thence into the Kupfer-schiefer and the overlying members, as in the large diagram at p. 334.

Permian Rocks surrounding the Chain of the Harz.—The older sedimentary rocks constituting the nucleus of the Harz, and the chief eruptive rocks of that remarkable region, will be described in a subsequent chapter. The Permian deposits which form a girdle around that mountainous mass which trends from W.N.W. to E.S.E., or nearly at right angles to the original direction of the older and elevated rocks, are quite analogous in their general relations to those of the Thüringerwald and the broad tracts to the west of it; but there are local features peculiar to the Harz which demand notice. As around the Thüringerwald we equally well see the same ascending order of the three chief subdivisions, all symmetrically united in one physical group, which is separated from the Upper Carboniferous rocks beneath, and from everything Triassic above it; in like manner, also, the conglomerates of the Roth-liegende are found to be local accumulations only, extremely thick in some places, and very thin, or even dying out, in others.

* The divisions of Roth-liegende, Zechstein, and Lower Bunter Sandstein were so correctly laid down by M. Ludwig in the Geological Map of the country to the N.E. of Frankfort, that the geologist has but to unite these three under one name, and he has at once my Permian group. The finest collection of the fossils from the Zechstein of the Wetterau is in the possession of M. Roessler of Hanau. Numerous Permian species of mollusks, corals, and entomostraca, which are common to Britain on the west and Russia on the east, are found at the localities of Selters, Bleichenbach, Haigründen, Büdingen, Rückingen, Niederzoderbad, &c.

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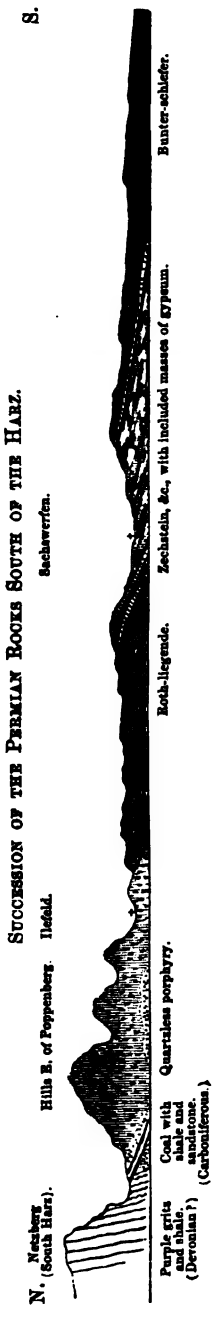

Referring to other works* for such variations of detail exhibited by the Roth-liegende and overlying deposits, as seen in the environs of Mansfeld and Eisleben, let me here reproduce† one long woodcut published by Sedgwick and myself twenty years ago, which shows at a glance the Permian succession to the south of the Harz in a district where the deposits are expanded.

There are still, however, two features in the Permian group as exhibited in the region around the Harz, which deserve more notice. These are, that the lower members of the Roth-liegende, which are not exposed at Eisenach (p. 334), are much developed; and next, that the upper member of the Zechstein is more largely composed of masses of gypsum, often amorphous, and attaining enormous dimensions.

Although there are many spaces along the southern and eastern flanks of the Harz, where the upper member of the Roth-liegende is well exhibited, particularly in its relations to the overlying Zechstein, and of which proofs have already been given, the tract where the inferior member is, as far as I know, most fully displayed is on the northern escarpment of the bold Permian outlier, the Kyfhauser;—so called from the ruins of an imperial residence, of that name, which stands on one of the north-eastern summits of this hilly and insulated mass.

On proceeding from Stolberg, and its old rocks, on the south flank of the Harz, and reaching the town of Kelbra in the rich valley termed the Goldene Aue, the surface of the red-coloured arable fields is seen to be studded with fragments, often 2 or 3 feet long by 1 or 2 feet in diameter, of silicified stems of fossil trees, which for the most part belong to those plants termed Araucarites and Psaronites; the latter being unknown in any other deposit save the Roth-liegende of the Permian group.

Standing on this red plain, the spectator has in face of him, to the south, a noble escarpment rising to upwards of a thousand feet high, the whole of which, ranging westwards from the ancient tower of the Kyfhauser by the Rotheberg, is composed of various strata of the Roth-liegende, whether of pebbly beds, sands, or shales, piled symmetrically on each other. In parts, as near the well-known and picturesque Hermitage on the Rotheberg, so much frequented by German summer tourists, the deposits have been broken through by eruptive rocks—chiefly syenitic greenstone; but a little to the west of this disturbance, all the strata are admirably exposed in the sides of the

* See memoir by myself and Prof. Morris, Quart. Journ. Geol. Soc. vol. xi. p. 409.

† From the Trans. Geol. Soc., 2nd ser., vol. vi. p. 286.

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great high-road leading to Frankenhausen, which, by a series of traverses, mounts up to the summit of the hills. Now, whether, in making that ascent, we examine the base, as composed of finely laminated, earthy, deep red sandstone, or the middle, of harder and thicker-bedded sandstones, or approach the summit, where light-coloured pebbly beds, used as millstones, are largely quarried—the latter being covered by other red marls and sandstones,—we find throughout numerous fossil trees, regularly imbedded, and lying either in horizontal positions or slightly oblique to the strata*.

To the west and south-west, these noble masses of red conglomerate and sandstone, followed by other red strata, are seen to be succeeded by the Zechstein, with huge associated bodies of gypsum, which in their turn are surmounted in the same hills by other red rocks.

Here again, therefore, as, indeed, everywhere in Northern Germany, the tripartite division is apparent, and the *Zechstein* (in this tract usually with masses of gypsum) is seen to constitute simply the central body of the great red Permian group.

There are, however, many spots along the south flank of the Harz, and also to the south of the Kyfhauser promontory, where the gypsum is swollen out to masses of enormous dimensions, and is devoid of a regular capping of red sand, or indeed of any superjacent stratified deposit. In these cases it would seem, that a former agency acting from beneath, along a great line of fissure, has greatly affected the rock, and changed the carbonates of lime into sulphates; for there are some places where the bedding and colour of the layers are still evident, and others, again, where the whole have been converted into amorphous and unstratified masses of huge dimensions. Not only do these masses of gypsum form lofty escarpments, usually blanched by atmospheric action, but at Frankenhausen, where extensive salt-works have long been carried on, the borings were made through 1173 feet, to reach the rock-salt. Now, in all this thickness, with the exception of the uppermost 93 feet, which consisted of red sand, apparently the detritus of the overlying red strata of the country, the whole subterranean mass was found to be gypseous, with occasional intercalations of limestone and argillaceous way-boards, as if to show that the substances had been once regularly stratified. This phenomenon, in a tract the northern part of which is characterized by stratified rocks of the same age and of no great thickness, affords a strong argument in favour of metamorphic action having proceeded from great depths, and of its having acted in this expansive manner along a line of fissure.

That this huge and irregular mass of gypsum at Frankenhausen is the result of a great change, is proved by proceeding southwards from the north along the high-road which traverses the Kyfhauser promontory. There, the lower flaglike calcareous layers of the Zechstein limestone are seen to be sloping away regularly, at a small angle, from off the red sandstones on which they repose. Next, after some contortions, the whole rocky, precipitous cliff, from the summits of which the watch-towers of the ancient town of Frankenhausen

* So numerous are these fossil trees, that ten of the largest are arranged around a central pyramid of other and thinner stems on the summit of the high road leading from Kelbra to Frankenhausen. The large silicified stems on the exterior, some of them 3 to 4 feet in diameter, form seats. One tree, lying *in situ*, and crossing the strata obliquely, measured 42 feet in length, with a diameter of 18 inches.

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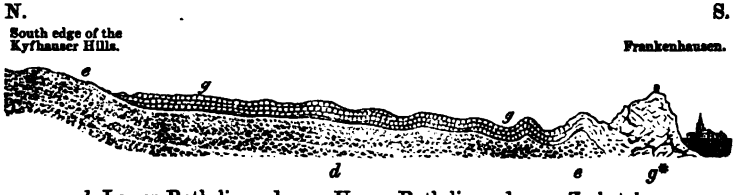
frown over the southern plains of red land, is seen to consist of gypsum, in most of which there is no regularity of stratification. But whilst the bore-hole at the base of this cliff was also chiefly made in gypsum, M. von Dechen informs me, that there were occasional interpolations of limestone and argillaceous schist with various sandstones†: so that, whilst the German geologists consider this gypseous mass as being subordinate to the Upper Zechstein only, I would suggest that the facts of the intermixture of such mineral substances looks very like the result of a great disturbance, accompanied by a considerable change of character in the rock. My own views are expressed in this generalized woodcut.

RELATIONS OF GYPSUM TO THE ZECHSTEIN AT AND NEAR FRANKENHAUSEN.



d. Lower Roth-liegende. *e*. Upper Roth-liegende. *g*. Zechstein. *g**. Altered Zechstein and gypsum.

The phenomenon of the vast expansion of gypsum occurs at various other places on the southern flank of the Harz, and is strikingly demonstrated at Artern, ten miles east of Frankenhausen, and probably on the same line of metamorphism. There, according to von Dechen, the strata, consisting of—1st, overlying red sandstone; 2ndly, gypsum; 3rdly, Zechstein in the form of stinkstein; 4thly, gypsum—were penetrated both by shaft and borings to the depth of 1017 feet before the rock-salt was reached‡.

In this way we obtain evidence that in Northern Germany, just as in the south-eastern Steppes of the Kirghis to the S. of Orenburg§ in Russia, the rock-salt and gypsum are fairly subordinate to the Permian group; both these mineral masses having apparently resulted from metamorphic action.

The geologist who follows the Zechstein along various tracts is constantly, indeed, induced to account in a similar manner for a sudden expansion of that bedded deposit into amorphous dolomite. For, although there are numerous tracts where the upper portion of the formation is a regularly bedded magnesian limestone resembling that of Britain, yet as we often see the rock, which at the distance of a mile is a flat-bedded, stratified limestone of small dimensions, suddenly swell out into a precipitous, amorphous mass, characterized by caverns

† I am indebted to my distinguished friend H. von Dechen, the celebrated geologist (now worthily the Chief of the Mines of the Rhenish Provinces of Prussia, and to whose great map I shall hereafter have occasion to refer), for all the information I possess respecting the borings at Frankenhausen. He further states that the gypsum was traversed by numerous cracks, the deepest of which was seen at 743 feet below the surface; such cracks being filled with sand and pebbles.

‡ After a visit to Salzungen in the company of Duke Bernhard of Saxe Weimar, I should infer that the saline waters of that place, which lie to the west of the Thüringerwald, and which German geologists have placed in the Bunter Sandstein, really rise, like the salines of Frankenhausen, Artern, and many other places, from rock-salt subordinate to the Permian group. The shafts at Salzungen having passed through the red sandstone, borings were made to a depth of 500 feet, in which gypsum was traversed, as well as dark argillaceous strata.

§ 'Russia and the Ural Mountains,' vol. i. p. 184.

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and irregular joints, it seems impossible to doubt that this change has also been caused by a powerful metamorphosis. This rapid change can be observed by any one who, frequenting the baths of Liebenstein on the west flank of the Thüringerwald, shall first examine the stratified Permian hills to the west of Glücksbrunn, with their strata of Weiss-liegende and Kupfer-schiefer surmounted by Zechstein and red flaggy sandstone, and then cross from the escarpment over several protrusions of porphyry in the valley to the east, which have much altered the strata in contact, until he is stopped by the precipitous face of the towering masses of dolomite which suddenly rise up, and constitute pictorial eminences 200 feet above the low tract, as in this woodcut.

CONVERSION OF BEDDED ZECHSTEIN (*g*) INTO AMORPHOUS DOLOMITE.

d. Roth-liegende (not seen in this part of the tract). *e*. Weiss-liegende with some copper ore. *f*. Kupfer-schiefer, rich in ore and fossil fishes. *g*. Zechstein, with fossils. *h*. Red sandstone, roof of Zechstein. *g**. Altered Zechstein (Dolomite). *. Eruptive rocks. *m*. Micaceous schist and altered rocks.

The identity of the amorphous subcrystalline dolomite of the cliff with the stratified limestone of the adjacent lower country, is here demonstrated by the clearest evidence; for the same species of shells which exist in the flat-bedded strata, *g*, of the low arable hills on the east are here detected in the unbedded wild cliffs of dolomite with their deep fissures and long caverns, *g**†.

In thus briefly alluding to the striking features of amorphous gypsum and dolomite which re-occur at intervals in many parts of the range of these limestones of the Permian group, it is also to be noted, that along these lines of metamorphism the same rocks often contain rich masses of spathose and hematitic iron ores. This is specially observable on the western flank of the Thüringerwald, to the east and south of Liebenstein, where the Zechstein has been intruded upon by porphyritic and granitic rocks.

In advancing from the environs of Saalfeld, where the Zechstein and Weiss-liegende (the latter becoming red in parts) rest upon the edges of the Upper Devonian and older Carboniferous rocks, we meet with numerous knolls of gypsum, both stratified and amorphous, with much iron ore, both of which have been described by Richter‡; whilst at Essig and Pössneck the calcareous matter again rises up in apparently unbedded dolomitic bosses, which on disintegration have afforded numerous characteristic fossils §.

† During my last visit to Liebenstein, I received the kindest attention from the accomplished prince, Duke Bernhard of Saxe Weimar, and was conducted by His Serene Highness not only through the splendid caverns, but also to those parts of the cliff of dolomite in which many bryozoa and mollusca of the Zechstein occur. Some of the finest collections, indeed, of Permian fossils have been extracted from the crystalline dolomites of other places in Germany.

‡ Einladungs Programm der Real Schale, &c., Saalfeld, p. 21.

§ The Altenburg of Pössneck has afforded to the researches of the Rev. Mr. Schubert a fine collection of fossils.

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Persistent in its character of contraction and great local expansion, the Roth-liegende, which has thinned out at Saalfeld, resumes its importance at Gera, near to which place it is to be partially seen, underlying and fairly passing into the Weiss-liegende; whilst to the north of that city, the lower red deposit, rising out from beneath all the Zechstein series, swells out to a vast thickness, and again occupies a broad tract extending far into Saxony on the north and east. The memoirs of Dr. Liebe, of Gera*, have fully explained the positions of the fossils which occur in such abundance in the environs of Gera, and which can be so well studied in the fine collection of M. Dinger of that town †.

The material point which I seek to establish is, that there, and on the right bank of the Elster, the geologist sees a section which leaves no doubt of the propriety of binding together the different members of the Permian group in the manner indicated.

It is true, that on the banks of the Elster, near Gera, the uppermost bed only of the Roth-liegende can be observed; but as this deposit has been pierced to a great depth in fruitless searches for coal on the opposite bank of the stream, no one can doubt that the true Permian foundation-rock is here developed on a great scale. The upper member of the Roth-liegende, which is there visible, presents all the unmistakeable characters of the deposit; being made up of fragments, more or less angular, of quartz, Lydian stone, and particles of the older rocks in a deep red, sandy paste, here and there spotted green. This rock passes gradually, and without the smallest appearance of discordance or separation, into a lighter-coloured conglomerate of about 10 feet in thickness, composed of broken fragments of quartz rock and greywacke, somewhat ochreous downwards, and becoming white, or light grey, upwards. The latter rock, containing many of the same fragments as the lower red mass, assumes in its upper part a calcareous and highly magnesian, instead of a siliceous and argillaceous paste.

Now, this whitish conglomerate, which is truly the upper part only of the Roth- and Weiss-liegende, and is conformably overlaid by the Kupfer-schiefer, already contains the following fossils, so typical of the Zechstein in various countries: viz. Productus Cancrini, de Vern., Lingula Credneri, Gein., Strophalosia (Productus) Leplayi, de Vern., Avicula, Pecten Mackrothi, v. Schaur., Terebratula Geinitziana, with the plants Ulmannia frumentaria and U. lycopodioïdes, Göppert, &c.

In this way the basement conglomerate rocks are linked on by these animal remains, as well as by chemical constitution ‡, to the calcareous central strata. At the same time it is worthy of consideration that the same species of mollusks were in existence whilst the action which evolved the inferior conglomerates was drawing to a close, and that even subsequent to the appearance of such mollusks a remarkable change occurred in the sea-bottom, by which the dark-coloured mud, occupied by the remains of peculiar fishes, and known as the 'Kupfer-schiefer,' was spread out over a wide region. But the calcareous element recur-

* See Zeitschr. Deutsch. Geol. Gesells. vol. vii. p. 406.

† Dr. Liebe and M. Dinger obligingly accompanied Mr. Rupert Jones and myself to the examination of the strata here described, and we were much gratified by the inspection of numerous beautiful fossils in the museum of the last-mentioned gentleman. The collection of the Rev. M. Mackrode is also celebrated.

‡ See Liebe's Notice on the conglomerate Zechstein, Zeitsch. Geol. Gesells. ix. p. 407, which shows an increase of magnesia from the Roth-liegende into the Weiss-liegende, and a greater quantity of it in the pebbly Zechstein than in the overlying Zechstein.

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ring, the same mollusca again flourished, and became still more abundant in the overlying Zechstein. The sections near Gera are so instructive, that, without entering into details, it is desirable to record a few leading data connected with the other or overlying strata of the Permian group. The Kupfer-schiefer, which is not here metalliferous, is a hard dark shale, containing relics of Palæoniscus, two or three mollusks, including Lingula Credneri, and the Cupressites frumentarius. It is followed by the chief fossiliferous band of limestone (the Zechstein of Schlotheim), which, though of small thickness (3 to 10 feet only), is laden with a profusion of well-preserved fossils, besides those known in the conglomerate beneath, such as Productus horridus, Solen pinnæformis, and Spirifer alatus. This limestone is covered by a darkish-coloured magnesian marl with concretions, in which some of the fossils of the inferior stratum no longer appear. The superjacent rocks consist of a hard grey rauchkalk, which on weathering becomes more dolomitic than when extracted from the quarry; its summit being known under the name of 'Ashe.' This flat-bedded calcareous series (in all about 70 or 80 feet thick) terminates upwards in thin layers of impure fetid limestone (stinkstein) with small fucoids. It is, however, to be remarked, that there is a still further continuation of the dolomitic character upwards, which has induced the local geologists to assign the name of 'Rothe Zechstein' to another and higher band, about 25 feet in thickness, of red and green marls, the geodes of limestone in which contain over 25 per cent. of magnesia. This band is, in fact, the uniting link in this part of the series, between the underlying Zechstein and that portion of the overlying sandstones, which here, as elsewhere, forms the natural summit of the Permian group. It is on this red sandstone, or uppermost Permian rock of my classification, that the palace of the Prince of Reuss stands.

Difference between the Permian Rocks of Northern and Southern Germany.—Although not yet very exactly defined in geological maps along its southern boundary, it may be said that, where the Permian group maintains its full characters, lithological, zoological, and geological, it is a northern deposit. Ascertained to exist at Spitzbergen *, we have evidence of its presence in the most northern parts of Eastern Europe, extending even to the White Sea, and ranging southwards throughout Russia, and on the western flanks of the Ural Mountains, to beyond 50° of north latitude, south of Orenburg. In following this parallel to the west, we see that it passes by the northern foot of the Carpathians, and that, trending between the Riesengebirge and the Alps, it traverses the smaller German States and the north of France, to the south of the British Isles; thus leaving to the north all that portion of Europe in which any Permian rocks are known. This geographical feature is dwelt upon, because it is essential to observe, that in following the group in Germany from north to south, it is found to part with its principal calcareous centre and fossiliferous member. Thus, to refer once more to the region of the Thüringerwald, rendered so classic by the map of that sound geologist Credner, and illustrated by the able publications of Professor Senft and Baron Schauroth, the paleontologist of Coburg, the Permian rocks are seen to part with their calcareous centre, as we track them southwards to the district lying between Neustadt and Kronach † in Bavaria. There, huge accumu-

* See description of the fossils from Spitzbergen by Leopold von Buch, and also by de Koninck.

† This interesting district was visited by me in 1854, accompanied by Professor Morris, when we were much indebted to

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lations of the Roth-liegende, overlapping in highly inclined positions a thin coal-field, are surmounted by a very poor and meagre band of limestone, which further southwards is entirely lost. Again, in approaching the Riesengebirge from the southern part of Prussia on the north, the Zechstein is exhibited for the last time in the tract near Löwenberg, south of Liegnitz. There, that rock, resting upon Roth-liegende, and dipping under red sandstone, is, as in other places, a poor and thin deposit when compared with its equivalents on the flanks of the Harz and the Thüringerwald.

As soon as we enter into the Riesengebirge, and thence travel southwards through Bohemia, or even through the southern parts of Saxony, from the environs of Dresden, we nowhere meet with a Zechstein formation like that of Northern Germany. In all this southern region the lower member of the group, preserving locally the ordinary characters of the Roth-liegende of the northern and western tracts, is one great series of sandstone and conglomerate beds, which, as in the Thüringerwald and the Harz, is ushered in with the evolution of porphyries. In this series are found many fossil plants, with here and there calcareous courses, often characterized by ichthyolites of the genera Palæoniscus, Pleuracanthus*, Acanthodes, &c.

Whilst these ichthyolites are like those of the Zechstein, except in the case of one of the genera known in the carboniferous rocks, they differ from the latter, as will presently be shown, in *specific characters*. In Lower Silesia, and particularly in the district between Friedland on the north and Braunau on the south, the lower members of these red rocks are finely laminated red sandstones, associated with, and in part reposing on, red porphyry; they are covered by other sandstones and conglomerates, and contain within themselves courses of darkish grey or reddish thin-bedded limestone charged with fishes. In examining a dark band of these limestones at Oel Berg near Braunau †, I could not avoid being struck with the analogy of its position and relations to that of the Zechstein of Northern Germany ‡. The limestone rests upon a black schistose bed, in which copper has been worked, and the whole, reposing upon a vast thickness of red sandstone, is immediately and conformably surmounted by reddish, purplish, yellow, and whitish grits, sandstone, and shale. In other parts of Bohemia, fishes similar to those of Braunau, Ruppersdorf, &c. have been detected in red flagstones. From what we saw, it is probable that there are two

M. Büttner of Kronach for conducting us to good sections of the coal-pits, some of which are worked under the Roth-liegende, and others in valleys below the natural escarpments of the red rock.

* According to Sir P. Egerton, Xenacanthus, Pleuracanthus, and Diplodus are all the same genus.

† Accompanied by Mr. Rupert Jones, I was conducted to this spot by my very intelligent botanical friend Dr. Beinert of Charlottenbrunn. To the west of this district, there exists the remarkable petrified forest of Radowenz and Buchau, near Adersbach, described by Professor Göppert, and to which M. Schroll and Dr. Beinert directed my attention: here, thousands of tons of silicified stems of trees, chiefly of the genus Araucarites, are found. I much regret not to have visited this sandstone tract, in order to satisfy myself if it really belongs to the Upper Coal, as suggested, or to the Lower Permian. The presence of the carboniferous plant, Araucarites Brandlingii, would by no means determine the question; for that plant does occur in true Roth-liegende; and Göppert has decided, that at Radowenz it is associated with the new form, A. Schrollii. See a translation of Göppert's account of this tree-bearing sandstone, as taken from the Memoirs of the Silesian Society, Ann. & Mag. Nat. Hist. ser. 3. vol. i. p. 236.

‡ Professor Naumann has shown how such fish-beds occur very low indeed in the Permian rocks at Oschatz in Saxony. (See Quart. Journ. Geol. Soc. Lond. vol. v. p. 2.)

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or more calcareous beds; for the limestone at Halbstadt, only a few miles to the north of Braunau, is a red and deep-purple-coloured rock, wholly unlike that of the Oel Berg, and not containing fishes.

Again, in the very heart of the conglomerates which, though apparently the oldest beds, constitute alone the whole of the Permian rocks visible to the north-west of Friedland, limestones containing magnesia occur. These brecciated masses and their limestones are well exposed at Traut-Liebersdorf, where the transition from a calcareous conglomerate replete with angular fragments of quartz into a coarse calcareous grit, and from that into a limestone, which attains a thickness of 30 feet, is readily seen.

At the Oel Berg near Braunau*, ichthyolites abound, with many good specimens of which I was supplied through the liberality of M. Benedict Schroll.

These fossils have been submitted to the examination of Sir Philip Egerton, who has pronounced them to belong to the genera Palæoniscus, Acanthodes, Xenacanthus (Pleuracanthus), &c.†

Of these ichthyolites, the most striking and the largest is a placoid fish, with a strong defensive spine inserted immediately behind the head. This is the Xenacanthus (now more properly called Pleuracanthus‡) Decheni of Beyrich. It is abundant at Braunau, together with three or four species of Palæoniscus, the chief of which, P. Vratislaviensis, occurs also at Ruppersdorf. Palæoniscus lepidurus and another, like P. Voltzii, occur here or at Ottendorf. There is also a species of Acanthodes, a genus remarkable for its minute square scales.

Now, no one of these fishes is of the same species as those of like genera which are found in the subjacent carboniferous rocks.

The same conclusion has been arrived at by Sir Philip Egerton in the examination of the fossil fishes of Klein Neundorf which I recently brought home from the spot. Thus, the Acanthodes gracilis from the bituminous schists of that locality, which have been considered to be subordinate to the Roth-liegende, has also been pronounced to be a species distinct from the A. Bronni of the Coal period; a generic resemblance only having led to an erroneous identification.

Notwithstanding the endeavours of my distinguished friend Professor Ferd. Roemer to clear up the ambiguous relations of the strata near Klein Neundorf§, the section appeared to me to be so very obscure, that, even if the ichthyolites found in the schists of that insulated spot had proved to be carboniferous (which they are not, but, on the contrary, distinct Permian types), no satisfactory inferences could be drawn. There, to the S.W. of the hamlet, schistose grauwacke, like the shillat of Cornwall, and probably of Devonian age, is observable in the ravines, between which and certain outcrops of Kiesel-schiefer and amor-

* My really scientific friend in this tract, and who was of great service to me, is the zealous botanist and palæontologist, Dr. Beinert of Charlottenbrunn, whose museum is most instructive, and whose beautiful Park, which he has opened to the public, is replete with the living and extinct forms of vegetable life, so placed in juxtaposition as to render it well worthy of a visit.

† As all the species from the Roth-liegende which have been rigidly compared by competent ichthyologists are found to be distinct from those of the coal deposits, I doubt the accuracy of M. Schnur, who has identified the Permian Xenacanthus Decheni with a fossil fish of the coal of Saarbruck. (See Zeitschr. Geol. Gesells. vol. viii. p. 542.) A noble specimen of the Xenacanthus Decheni (15 inches long) from Ruppersdorf is to be seen in the Museum at Bonn (see Neues Jahrbuch, 1849).

‡ See note by Sir P. Egerton in the Ann. of Nat. Hist. for Dec. 1857, vol. xx. p. 423. The author shows that Diplodus is founded on the teeth of this genus.

§ Zeitschr. Geol. Gesells. vol. ix. p. 51.

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phous crystallized limestone, and showing no visible connexion either with the Roth-liegende or Zechstein, lies the dark flaggy schist used for slating purposes, which contains fishes and plants. M. Sachse of Löwenberg obligingly accompanied me to the ground, and from him I obtained specimens of Acanthodes gracilis and other fishes, all distinct, according to the latest examination, from Carboniferous species.

The opinion therefore of M. Beyrich, that the Roth-liegende should be classed with the coal deposits, receives the same refutation by a rigid appeal to the animal remains, as it does from a thorough scrutiny of the vegetable contents of the deposit, as will be shown hereafter on the evidence of Professor Göppert.

The immediate neighbourhood of Dresden has also proved to be very illustrative of the great mass of the lower Permian rocks, under the able researches and classification of Professor Geinitz. Every geologist who visits the admirable collection in the Zwinger gallery, still more if he has explored the tracts where the specimens have been obtained, will recognize the value of such a labour*.

The lowest portion of the Permian rocks of Dresden overlying the coal, which is worked, is a grey conglomerate, made up of fragments of granite, quartz, and older rocks, including even those of the upper coal strata, over the surface of which the deposit ranges transgressively. Schistose in aspect, and becoming reddish in parts only, this bottom rock, which obtained its light colour from the breaking up of the whitish upper carboniferous sandstone, contains indeed a few layers of coal formed out of true Permian plants, including the remarkable genus of Palm, Guglielmites Permianus, so named by Geinitz on account of the resemblance to the Guglielma speciosa of the Brazils described by Martius. With this plant are associated the Calamites gigas, Brongn., the Walchia filiciformis, Sternberg, many Psaronites, and the great Araucarites Saxonicus, some of the silicified stems of which, ornamenting this splendid and instructive museum, have a diameter of 3 feet. Passing up through this lower zone, which has a thickness in one shaft in the Plauensche Grund near Dresden of about 320 feet, we come to the chief mass of the Roth-liegende, in this district between 500 and 600 feet thick, and perfectly conformable to the underlying grey rock. This mass is made up of the debris of all the more ancient rocks of the neighbourhood, including much Lydian stone, granite or granatite, gneiss, grauwacke, and porphyry, some of the fragments being in fact gigantic, as seen near Tharande. This rock is also associated with bands of porphyry, which Geinitz, considering it to have been contemporaneously deposited with the conglomerates in the form of lava, has termed 'schlam-lava'; this, though truly an igneous rock, is as regularly bedded and jointed as the red strata with which it alternates. In the same tract, indeed, as in many other parts of Central Germany, the dejections of porphyry and amygdaloid have been occasionally so mixed up with sand and pebbles of the then existing sea, as to render it difficult to decide whether the stratum should be referred to an aqueous or to an igneous origin.

Calcareous matter is here and there sparingly distributed, and a coprolite has been detected and described by Geinitz. A limestone band, occurring at Schereindorf in the Plauensche Grund, and lying between the upper and lower or grey member of the Roth-liegende, contains a few indistinct bivalves and fishes.

* As the fine old collection was destroyed by fire, the untiring exertions of Professor Geinitz, by which it has been brought to its present high condition in so short a space of time, may well be eulogized.

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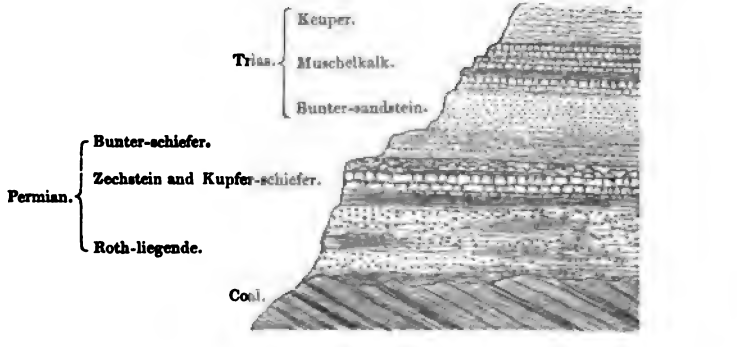
Of the numerous fossil plants of these Permian deposits in the environs of Dresden, and thence extending over the adjacent tracts of Saxony and Bohemia, it is sufficient to state for the present, that four or five species only are also known in the subjacent coal strata; thus completely sustaining the conclusions drawn by Geinitz and Gutbier* as to the independence of the Permian flora,—an inference which, as will presently be shown, has recently been amply confirmed by Göppert.

In taking a general view of the Permian rocks of Germany, we see that they differ chiefly from those of Russia in their lithological divisions, by exhibiting a much more massive development of the lower member, or the Roth-liegende, over large areas, and in not having yet offered in their superior member, or the red beds above the Zechstein, those numerous plants and saurians which characterize the upper Permian sandstone and conglomerates of Russia. On the other hand, by detecting in Germany many of the plants in the red rocks *below* the Zechstein which in Russia lie in red rocks *above* that rock, all the members of the group are united by paleontological evidences.

In a general sense it may indeed be said that the Permian of Germany is a lower or paleozoic Trias, the central mass of which is the Zechstein



limestone, with red sandstone above and below it; whilst the Upper or secondary Trias is also marked by its middle limestone, the Muschelkalk, with its underlying Bunter Sandstein and its overlying Keuper marls.

But whether the lower 'Bunter' be abstracted from the Trias or not, let me again call attention to the fact, that, whilst the Permian and Trias are conformable to each other, and exhibit nowhere any of those disseverments which mark the separation of the lower from the upper coal of the Continent, and again the close of the coal deposits, their respective fauna and flora are, according to the present state of knowledge, entirely dissimilar. The Permian exhibits the last traces of primeval life, whilst

* See Versteinerungen des Permischen Systemes in Sachsen. Dresden and Leipzig, 1849. Out of sixty species of these Permian plants from Zwickau in Saxony, forty are exclusively of Permian age, and several are identical with forms from Russia, which there lie in strata above the Zechstein.

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the Trias is charged with the exuviæ of plants and animals entirely distinct from all those which preceded them.

The general succession, which for the most applies to Western Europe, is expressed in the preceding diagram; though, as before said, there are tracts, particularly in Russia, where these Permian rocks repose with apparent conformity on the subjacent coal strata.

Permian Rocks of Britain, &c. (See No. 8 of the Map*.)—The Permian rocks of Britain, where they are most clearly developed, consist in ascending order, of the lower red and yellow sandstones and conglomerates, the equivalents of the Roth-liegende; the marl-slate and Magnesian Limestone, the equivalents of the Kupfer-schiefer and Zechstein; followed by certain bands of red sand and marl, as expressed in the preceding diagram. The best types, particularly of the calcareous or central portion of this succession, are to be seen in the counties of Durham, York, and Nottingham, where they were long ago admirably described by Professor Sedgwick†, and compared by him with the German deposits of like age. Let us therefore first treat of the group in those districts where the clearest relations of its chief parts are best exhibited.

In Durham the *lower sandstone* is well exhibited at Clacksheugh, three miles west of Sunderland, where, on the left bank of the Wear, its lowest portion is a dull red sandstone‡, lying far above all those strata in which traces of coal have been found. This red rock gradually assumes a mottled yellow and red colour, whilst in ascending, the yellow colour exclusively prevails in the escarpment on the right bank of the river, where a soft yellow sandstone, about 100 feet thick, and in parts quarried as a freestone, forms the natural and conformable support of the mass of magnesian limestone, the structure of which has been well exposed by the cutting of a railroad. These red and yellow sandstones, absolutely dovetailed into each other by mineral characters, exhibit features which are not seen in the underlying carboniferous rocks, and particularly in containing many laminæ of false bedding; whilst their upper and harder courses, gradually becoming slightly calcareous, pass up into the thin flaglike strata constituting the base of the Magnesian Limestone; both rocks partake of the same flexures.

The yellow sandstone with white incoherent beds, and an overlying marly

* The Permian rocks, as defined in the work on Russia, were first laid down on a Geological Map of England constructed by myself in 1843, and published by the Society for the Diffusion of Useful Knowledge (see also new edition (Stanford) 1856).

† See Sedgwick on the Magnesian Limestone (Trans. Geol. Soc. 2nd series, vol. iii. p. 37).

‡ English geologists will perceive that my views respecting the underlying red and yellow sandstone, passing up conformably into the Magnesian Limestone, are not in accordance with those proposed by Mr. R. Howse (Ann. Nat. Hist. 2 ser. vol. xix. p. 36), in which he unites these sandstones with the Carboniferous series. I do not admit that the occurrence of a few plants said to be of Carboniferous species in the underlying red sandstone at Tynemouth affects my conclusions as to the true base of the Permian. In visiting both banks of the Wear near Clacksheugh, accompanied by Mr. Talbot Aveline, we saw proofs of such a gradual passage of the red sandstone into the yellow sandstone, and of the latter into the magnesian limestone, that I necessarily group them according to the classification of Professor Sedgwick. I am bound, however, to say, that the memoir of Mr. Howse displays talent and assiduity, and must be considered a valuable contribution to the history of the Permian rocks and fossils.

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flagstone, are traceable at intervals through the county of Durham, along the foot of the escarpment of the Magnesian Limestone by Sherburn and Ferry Hill, and have been traversed by numerous shafts of the more recently made coal-pits.

In numerous places the limestone is united to the sandstone by means of a flaglike marlstone, called marl-slate by Sedgwick, who has shown it to be the equivalent of the Kupfer-schiefer of Germany; it contains Lingula Credneri, Gein., and fossil fishes of the genera Palæoniscus, Pygopterus, Cœlacanthus, Acrolepis, and Platysomus.

The overlying yellow magnesian limestone is most fully exhibited in the bold line of coast cliff extending from Sunderland to Hartlepool, where its lithological varieties and peculiarities, including large round concretions and beds of flexible sandstone, were completely described by Sedgwick*. In its range southwards through Yorkshire, this rock is characterized by Axinus obscurus, and, though lost for a certain distance under younger deposits some miles to the south of the Tees, becomes again an important formation between Doncaster and Nottingham. Formerly it furnished materials for the construction of the old cathedral churches of York, Beverley, and Ripon, and recently it has afforded the chief building-stone for the Houses of Parliament. The accuracy of the sections described by Professor Sedgwick so many years ago, in showing the relations of this limestone to the sandstone beneath it, and to certain red and occasionally sandy strata above it, as exposed in the southern parts of Yorkshire, has recently been demonstrated by the cutting of the railroad from Bradford to Doncaster. In that traverse, the observer, who proceeds from west to east, no sooner leaves the coal-field, than he passes by, 1st, a thin band of lower red sandstone; 2nd, a great mass of the thick-bedded magnesian limestone; 3rd, a zone of red marl with gypsum; 4th, the thin-bedded limestone so largely worked in Yorkshire, and which, containing traces only of magnesia, is preferred for agricultural purposes; and 5th, red sands and marls, which range up to the town of Doncaster, and form the summit of the whole group. But to return to the consideration of the basement-rock of the group.

Obscured by overlying formations and detritus in the North Riding of Yorkshire, the red and yellow sandstones emerge in force between Ripon and Knaresborough, and under the castle at the last-mentioned place are surmounted in a striking cliff by the Magnesian Limestone, precisely in the same manner as in Durham; the lower part of the yellow rock passing also down into a thick-bedded, deep red, hard, sandy grit. In this district, indeed, and particularly on the banks of the Nid near Knaresborough, the inferior red member rises up into marked and distinct physical masses, which locally merge into an angular and subangular quartzose conglomerate, which is undistinguishable from the Roth-

* The reader who desires to become acquainted with the details of the structure and contents of the Magnesian Limestone and associated strata should consult the following works:—Sedgwick, Trans. Geol. Soc. 2nd ser. vol. iii. p. 37; King, Monograph Perm. Foss., 1850, and Ann. Nat. Hist. 2nd ser. vol. xvii.; Howse, *ibid.* vol. xix.; Binney, Mem. Lit. & Phil. Soc. Manchester, vol. xii. and vol. xiv. The six subdivisions, in ascending order, of Marl-slate, Compact Limestone, Magnesian Conglomerate, Shell-limestone, Botryoidal Limestone, and Upper Yellow Limestone, given by Mr. Howse and repeated by Mr. Davidson, as the details of the Permian group (Palæontograph. Soc. Monog. 1856), are here omitted. They are, in fact, merely local subdivisions of the Magnesian Limestone of Durham, and altogether form the calcareous or central part only of the natural group defined as Permian in Russia and Germany by myself and associates.

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liegende of the Germans. Whilst revisiting these scenes of my youth in the autumn of 1857, in company with Mr. Aveline, immediately after a tour in the Thüringerwald, Harz, and Bohemia, I had no hesitation in affirming that the well-known picturesque 'Plumpton Rocks' near Harrogate are identical with the quartz conglomerates of Germany (p. 334), whether as regards their ingredients, colour, false bedding, or massive stratification.

In tracing the lower sandstones southwards through Yorkshire, they are seen to be quarried in many places to the west of Bramham Moor, and at Pontefract they are largely worked. There, the yellow 'Pontefract rock' of William Smith* is again clearly seen, as in Durham, to form the natural base of the Magnesian Limestone.

The lowest visible beds at Pontefract are also occasionally of a red colour, but the great mass of conglomerate and breccia, as exposed in the Plumpton Rocks, is no longer to be detected; the bottom beds being simply hard, deep red, flaglike, micaceous grits. These are surmounted by yellow sandstones, in parts of whitish colours, which are extensively used as building and trough stones; some portions being so porous as to make excellent filters. Occasionally, indeed, the stratum is so incoherent as to be used only as scouring-sand.

To the south of Pontefract the lower sandstones, both red and yellow, begin to thin out; and, though they are recognizable on the banks of the Don, and under the Castle of Conisborough, the band is greatly reduced in thickness, and exhibits little more than a reddish, micaceous, flaggy rock, with shale, &c. Still further to the south, this lower sandstone, as exposed on the eastern side of the Pennine chain, and to the east of the South Yorkshire coal-field, is diminished to a mere bed, which expires altogether in the environs of Nottingham. There the Magnesian Limestone rests at once upon the coal-measures.

Thus, this lower member of the Permian group, as seen on the eastern side of the Pennine chain, exhibits, though on a less scale, the chief peculiarities of its German equivalents. In one place a fine sand, in another a coarse grit, in a third a breccia or conglomerate, and always varying much in dimensions, it has evidently been formed on the eroded surfaces of the pre-existing carboniferous rocks. But however variable in thickness it may be, as depending upon the method of accumulation, we invariably perceive that its upper beds graduate into, and form the natural bottom of, the Magnesian Limestone, as formerly demonstrated by Sedgwick†.

In the sequel it will be seen how greatly this lower member of the Permian group is expanded on the western flank of the Pennine chain.

Professor King, who had long studied the fossils of the calcareous members of the group in the county of Durham, has placed the detailed component parts of the Permian group still more closely in comparison with the corresponding beds of Germany. Thus, whilst, with Sedgwick, he considers that the lower sandstones of Yorkshire and Durham, whether red, white, or yellow, which lie between the coal and the Magnesian Limestone, are the true equivalents of the German Roth-liegende, and that the marl-slate, with its fishes, stands in the place of the copper-slate of Germany,—he also shows that the fossiliferous

* So named by William Smith, the 'father' of English geology, whose lessons in the field along the Yorkshire coast (1826) were of great service to me.

† See Sedgwick on the Magnesian Limestone, Trans. Geol. Soc. Lond. 2nd ser. vol. iii. p. 37.

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beds* of compact limestone represent the lower, and the brecciated and concretionary limestones of Durham the upper Zechstein of the Germans, with its overlying beds of dolomite, rauchwacke, and stinkstein.

In England there is, perhaps, no other yellow limestone so charged with magnesia as to form a true dolomite; and hence, in the early days of geology, it was natural to define this rock as *the* Magnesian Limestone†, and to associate with it certain subordinate strata. But now that yellow magnesian limestones are known to occur, on a stupendous scale, in the Lower Silurian rocks of North America ‡,—in both the Devonian and Carboniferous series of Russia,—partially even in the carboniferous limestone of Derbyshire,—and whilst the Jurassic masses of the Alps are to a great extent crystalline magnesian limestones or dolomites §,—it became necessary to abandon the term 'magnesian,' and to place the English formation under a general name derived from a vast region, where the position and fossil contents of the group are clearly exhibited.

The Permian deposits, as developed in Russia, and also in Germany and England, do not stop, as before said, in the ascending order with the Zechstein. They include another overlying red sandstone, which in many parts of Germany, as already shown, also constitutes the conformable roof of the Zechstein, and contains the plant Calamites arenarius, Brongn., with its carboniferous aspect. In Russia, indeed, some of these overlying red beds are charged, as we have seen, with the shells of the Zechstein and plants of the Roth-liegende. In general language, therefore, the Zechstein of the Continent, and the Magnesian Limestone of England, may be viewed as the calcareous centre of an arenaceous group, or, as before said, a lower 'Trias'; the upper red marl and sand of Yorkshire, described by Sedgwick, being as much a parcel of it as those red sandstones and conglomerates, or 'Roth-todt-liegende,' which in Western Europe lie beneath it.

In the Ardennes these rocks, so diversified elsewhere, are represented by a mere band of pebbly, siliceous conglomerate, which, being sterile of fossils, was named '*Penéen*' by M. d'Omalius d'Halloy‖. In France, *i. e.* in the Vosges, and at Lodève in Dauphiné, this group has not the distinctive characters, lithological or zoological, which it exhibits in Russia, Germany, and Britain, being chiefly a red sandstone. But in the Department of L'Aveyron (particularly in the neighbourhood of Alboy) it has been recently described as containing some calcareous courses representing the Zechstein¶. In that tract it is also distinguished, as in other regions, by a peculiar flora, containing certain ferns and conifers, which M. Adolphe Brongniart classes with Permian plants.

* See Professor King's 'Monograph of the Permian Fossils of England,' published by the Palæontographical Society, 1850, in which he describes 217 species of shells, corals, and other animals, many of them common to Germany and Russia.

† I am, however, disposed to think that some of the yellow beds of the carboniferous limestone of the Clee Hills are exceptions. (See Sil. Syst. p. 119.)

‡ See Dale Owen's Geology of Wisconsin, Iowa, and Minnesota, with a Map, on which vast magnesian limestones are laid down as the Lower Silurian of that author. 1853.

§ True dolomite, whether crystalline or earthy, is known by its containing 45 per cent. of magnesia. Another proof of the inapplicability of mineral terms to designate the age of strata is the use of the term 'oolitic' for rocks which in England have a lithological structure that is scarcely ever found in their continental Jurassic equivalents. 'Magnesian Limestone' is also merely an insular and misleading name.

‖ Elémens de Géologie, p. 276.

¶ See the memoir of M. Coquand, Bull. Soc. Géol. de France, vol. xii. 2me série, p. 128.

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In proceeding from the northern to the central and south-western counties of England, or again to the S.W. of Scotland, the Permian group undergoes also considerable changes in lithological structure, and the absence of limestone is accompanied by a diminution of the number of its characteristic organic remains. In Nottinghamshire, and to some extent in Derbyshire, limestone being still present, the north-eastern or Durham type is preserved; but at Manchester we no longer distinctly trace the Magnesian Limestone as a separate mass; though its place is taken by red marl and shale, with some thin courses of limestone subordinate to red sandstone, in which are casts of the common species of Schizodus, Avicula, Turbo, Rissoa, &c.,—an unmistakeable Permian assemblage.

Following the formation into the north-western counties from the tracts in Lancashire, where he has copiously exhibited its relations to the Coal beneath, and to the New Red Sandstone above, Mr. Binney* has estimated the maximum thickness of the group in that region at 1160 feet: viz. Upper Red marls with gypsum in the north, and nodules of limestone in the south, 300 feet; Magnesian Limestone with fossils, 10 feet; Lower Red Sandstone, 500 feet. If, as Professor Sedgwick thinks, the lower purple sandstone of Cumberland, which there immediately overlies the coal, belongs also to the Permian rocks, then these dimensions must be largely augmented. At all events, if we take the maximum thickness of each subdivision as now known to us, and where each is most developed, we shall not exceed in estimating the Permian group of Britain at the dimensions of at least 2000 feet.

Admitting that the red rocks overlying the coal of Cumberland belong to this age, it follows that the similar rocks which range into Dumfriesshire, and have there undergone many of the same movements as the carboniferous rocks, are also of the Permian epoch. In this way, as I suggested, indeed, some years ago†, the sandstones of Corncockle Muir, near Dumfries, so celebrated as exhibiting the footprints of the large sauroid and other reptilian animals, illustrated by Sir W. Jardine‡, fall into this category. The importance of thus working out the clear definition of the rocks which really pertain to this upper member of the paleozoic series will be more apparent at the close of this chapter, when we enumerate all the classes of fossil animals which are known to be of Permian age.

It is also with good reason believed that much of the red rock which overlies the coal of Ayrshire is of Permian age, as well as those red sandstones in the southern part of the Isle of Arran, which Sedgwick and myself classed as the New Red Sandstone at a period when the Permian classification was unknown.

In the endeavour to trace the Permian rocks to the south of the Manchester tract, we lose the clear evidence of the fossiliferous limestone centre, though calcareous conglomerates and breccias do occur above the Lower Red Sandstone, and may probably be viewed as representing the magnesian limestone of the northern counties. Such, at least, was my opinion when I described these rocks many years ago, particularly as exhibited in Shropshire, Staffordshire, and Worcestershire. In those tracts the Lower Red (erroneously called the Lower *New* Red before the term Permian was proposed) is an arenaceous formation of considerable dimensions, which, as I then showed, had been very successfully bored through

* Memoirs of the Lit. and Phil. Soc. of Manchester, vol. xii. Session 1854–55.

† See Quart. Journ. Geol. Soc. vol. vii. p. 163, and vol. xii. p. 267.

‡ See Sir W. Jardine's 'Ichnology of Annandale.' Some of the tracks have been referred to Batrachian, and others to Chelonian reptiles.

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in search of coal (Sil. Syst. p. 58). To the south of the Staffordshire coal-field, such Permian strata are seen to rest on the Upper Carboniferous beds.

In that district calcareous matter so abounds in the red Permian rocks as to constitute zones of earthy, subconcretionary limestone, which were pointed out as being undistinguishable from cornstones of the Old Red Sandstone of the adjacent county †. Thus, lying between two red deposits of similar structure, the position of the coal of Staffordshire and Shropshire realizes the aphorism of Humboldt, "que le terrain houiller n'est qu'un accident dans le grand terrain du grès rouge."

The irregularity of succession between the coal and these Permian rocks has been defined by Mr. J. Beete Jukes as occurring around the S. Staffordshire coal-field; and on the left bank of the Severn, between Enville and the Forest of Wyre, the whole of the Permian series is thus represented by Professor Ramsay ‡.

SECTION OF THE PERMIAN ROCKS BETWEEN THE COAL OF THE FOREST OF WYRE AND THE NEW RED SANDSTONE OF ENVILLE.

S.W. N.E.

a. Coal-measures. *b*, *c*, *d*. Permian rocks (*b*, sandstone and red marl with beds of calcareous conglomerate; *c*, coarse breccia; *d*, sandstone and red marl). *e*, *f*. Bunter Sandstone (*e*, lower brick-red variegated sandstone; *f*, pebble beds, or conglomerate). (*. Faults.)

In this diagram we see where the coal strata, *a*, lie unconformably beneath the red sandstone, *b*, with calcareous courses and concretions, and how both deposits have been upcast by a great fault, *a**. We further observe the order of the Permian rocks in this tract to consist of, *b*, sandstone, marl, calcareous courses, and conglomerates beneath, overlaid by a breccia, *c*, charged with fragments of igneous rocks. Above the last-mentioned are the highest beds of the Permian group in this quarter, consisting of red sandstone and marl, *d*; the whole series being crowned by unconformable beds of other red sandstones and conglomerates, *e*, *f*, which constitute the lower members of the Trias or New Red Sandstone.

At Alberbury and Cardiston in Shropshire, a calcareous conglomerate overlying the Lower Red Sandstone, and dipping under other red strata, assumes so much the character of a bedded, though brecciated, limestone, and also contains so much magnesia, that I still consider it to be probably the equivalent of the Zechstein (see Sil. Syst. p. 63).

In advancing from the centre towards the south of England, one member only of this group of rocks is exposed. Thus, the peculiar hills that range along an axial line from Abberley to Malvern, and which, on account of the vast quantity of igneous materials contained in them, I formerly considered to be of eruptive origin, have since been proved by Professor Phillips § to be a re-aggregated trappoid breccia. Professor Ramsay ‖ has lately shown, that this rock is of the same age as the breccia, *c*, of the last diagram, and that, besides felspathic and porphyritic materials, it contains subangular blocks and fragments of old slaty rocks, mostly derived from the Longmynd Mountain in Shropshire, and the rocks of the adjacent country of Shelve, described in the second and third chapters of this

† Silurian System, p. 55. Also Mr. J. Beete Jukes, in Records of the School of Mines, vol. ii. p. 160, &c.

‡ Quart. Journ. Geol. Soc., Aug. 1855.

§ Mem. Geol. Surv. vol. ii. pt. 1. p. 112.

‖ Journ. Geol. Soc. vol. xi. p. 155.

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work. The exact place of these breccias in the Permian series, which there separate the Old Red from the New Red Sandstone, will be eventually defined by the Government Surveyors, who will also precisely coordinate the other varieties of this British group, whether they be the red, yellow, and white sandstones overlying the coal and supporting the Magnesian Limestone, or the varied equivalents of that rock and its overlying red and sandy marls, &c.

In parts of their range through the central counties, the Permian rocks have been found to contain plants. At Allesley, for example, near Coventry, such fossils have been long known as existing in a highly silicified matrix, like that which encloses the stems described in the Roth-liegende of Germany.

The rock in which these plants occur has only very recently been separated from the New Red Sandstone, with which it was formerly classed, through the detailed examination of Professor Ramsay and his associates. Geologists who now acquire possession of the newly-coloured maps explanatory of the structure of those central tracts may be surprised to find, that so much of the red sandstone which ranges up to near Warwick also forms part of the series of Permian rocks; some casts of certain Permian shells having even been found near Exhall. The best fossiliferous British types of the Permian group are, however, only to be seen in the counties before enumerated, which lie to the north of the river Trent.

In the north of Ireland, the true equivalent of the Magnesian Limestone—similar in mineral character and in fossils to the rock in Durham and Yorkshire—has been recognized. A small patch of it occurring at Cultrea, on the south side of the Bay of Belfast, was first noticed by Mr. James Bryce *, and subsequently the fossils were described by Prof. King as species of Schizodus, Mytilus, Arca, and Pleurophorus. Recently, the latter author, examining another fossiliferous locality† (Tullyconnel Hill, near Artrea, in Tyrone), observed that the parent rock was a sandy dolomite, which, like that at Belfast, overlies the carboniferous limestone, and seems to dip under red sandstone. Among the thirteen species of fossils from Artrea, described and figured by King‡, Mytilus squamosus, Bakevellia antiqua, Schizodus obscurus, Pleurophorus costatus, and Turbo helicinus, are common to the deposits of the same age in England and the Continent, including the far north-eastern Petschora-Land of Russia, whence some of those species were brought by my associate Keyserling. The other forms, including corals and bryozoa, abound in the Magnesian Limestone of England. Thus, it is now ascertained, that the sea in which those peculiar animals flourished, extended from the eastern to the western extremity of Northern Europe, or over a breadth of about 2500 miles!§

In comparing the Permian deposits of England with those of Germany, it is worthy of remark, that, when examined from north to south, the mineral masses are, on the whole, found to succeed each other in a similar manner in the two countries. Thus, it is in the English northern counties, only, of Cumberland, Durham, Yorkshire, and Nottinghamshire,

* Journal of the Geological Society of Dublin, vol. i.

† Major-General Portlock had formerly transmitted fossils from this locality to Dublin.

‡ 'On Irish Permian Fossils,' Journ. Geol. Soc. Dublin, vol. vii. pl. 1.

§ Permian fossils have lately been discovered in Texas, in beds overlying coal-deposits.

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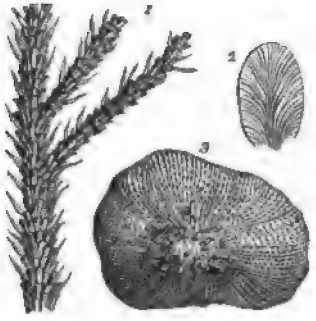
that we meet with the true Magnesian Limestone, or Zechstein, and its associated fossils; whilst in Lancashire, Shropshire, Staffordshire, Worcestershire, and Warwickshire, the whole group is represented, as in Southern Germany, by red sandstone, breccia, and conglomerate, with occasional traces only of calcareous matter.

Permian Fossil Remains.—The fauna and flora of the Permian rocks are, as before stated, essentially paleozoic; for, whilst in great measure they are specifically distinct from those of the Carboniferous system, the amount of agreement in the two groups is surprising, when we reflect upon the phenomena, adverted to in opening this chapter, of great physical revolutions which pretty generally affected the known surface of the earth at and before the close of the preceding or Carboniferous era. Those disruptions, therefore, however violent and extensive, were not universal, but were, we may suppose, so accompanied by new physical conditions, as to occasion the destruction of many species of plants and animals.

The Permian flora has not been yet so developed in the British Isles as to show in what degree it differs from that of the Carboniferous group, to which, in fact, it everywhere bears a resemblance. Mr. Howse, indeed, has said that some of the species found in the red sandstones of Tynemouth are identical with coal-plants; and, if so, that rock must be considered as Carboniferous. At Ashby de la Zouch, Sternbergia has lately been detected, together with silicified wood, by the Rev. W. H. Coleman; whilst the recent researches of the Geological Survey have shown, that much of the red rock of the central counties, formerly called New Red Sandstone, is of Permian age, and that among these masses must be included the rock of Allesley near Coventry, which has afforded many silicified

FOSSILS (85). PERMIAN PLANTS AND BRYOZOAN.



1. Caulerpa? selaginoides, Sternberg. 2. Neuropteris Huttoniana, King. Both are from the Marl-slate of Durham.

3. Fenestella retiformis, Schlotheim; "Magnesian limestone" of Humbleton Hill. The figures 1 and 3 are much reduced.

stems of plants. Professor Sedgwick* long ago pointed out the traces of Calamites in the Lower Red Sandstone, and various specimens collected by him and other geologists belong certainly to carboniferous genera, as in other countries; but scarcely any of those which have fallen under my observation are sufficiently well preserved to afford specific characters. In those beds, however, which are subordinate to the Magnesian Limestone, the forms are so well preserved, that no difficulty exists in distinguishing them, as in the accompanying figures of two

* Proc. Geol. Soc. vol. i. p. 344. Calamites occur also near Exhall.

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fossil plants, found in the marl-slate of Durham, from Professor King's elaborate work*.

In certain foreign tracts, however, which have been examined in detail, the Permian strata contain many more plants. The sandstone of Lodève, before adverted to, affords, according to M. Ad. Brongniart, ferns of the genera Sphenopteris, Pecopteris, Neuropteris, Alethopteris, and Callipteris, with Annularia floribunda (Sternberg), and several conifers of the genus Walchia†. The sandstone and conglomerates (Roth-liegende) near Zwickau, in Saxony, have rewarded the researches of Colonel Gutbier‡ with about sixty species of plants. A few of these only are known in the Carboniferous epoch; the greater number of the species being unknown in any other deposit. Among the plants most characteristic of the group may be mentioned the Sphenopteris erosa, S. lobata, and the great, reed-like Calamites gigas. Whilst in Russia these species of plants are chiefly found above the limestone courses, they are confined to the lower strata of Saxony, and are there commingled with some species known in the upper coal deposits. The large silicified stems of tree-ferns, called Psaronites, so much admired by collectors for the exquisite conservation of the fibre of the plant, and for the beautiful polish they take, occur abundantly in the lower red (Permian) beds of Germany§.

On the whole, it was the opinion of Adolphe Brongniart, to whom the plants brought from Russia were referred (plants, I repeat, which occur there in red sandstones and marls above, or interlaced with fossiliferous Zechstein), that they exhibit a continuation of vegetable life with characters to a great extent like those which prevailed in the Carboniferous era. But, whilst a few of the forms are the same as those of the Coal period, the species, with very few exceptions, are different||. On the contrary, no one of the Russian Permian genera, Neuropteris, Odontopteris, Lepidodendron, Sphenopteris, Nœggerathia, &c., occur in the overlying Trias, in which, notwithstanding the clear proofs of conformity and mineral passage between the two groups, the geologist has before him an entirely different flora.

Thus, Professor Göppert has found in the Roth-liegende and Kupfer-schiefer of Germany, and in the Permian rocks of Russia, 182¶ species of plants, of which 169 occur in the Roth-liegende alone, or lowest member of the group.

This accomplished botanist has favoured me with the following enumeration of the number of species in this group, as condensed from a work which he is about to publish:—viz. Fuci, 2; Equisetaceæ, 5; Calamites, 10; Filices, 97; Lycopodiaceæ and Lepidodendraceæ, 11; Walchiæ, 5; Gramineæ (doubtful); Nœggerathiæ, 4; Palmæ, 1; Asterophyllites, 6; Annulariæ, 3; Sigillariæ, 2; Cycadeæ, 9; Coniferæ, Cupressaceæ, and Abietaceæ, 20; fruits undetermined, 6.

The essential result of this examination is, that, in comparing the Permian

* Monograph of Permian Fossils, 1848, pl. 1, &c.

† See Russia in Europe, &c. vol. i. p. 219.

‡ Geinitz und Gutbier, Geea von Sachsen, 1843. For the figures of these plants, and sections showing their position, see 'Permische System in Sachsen,' 1850.

§ The finest collection of these 'Psaronites' extant, with which I am acquainted, is that of my friend, the eminent botanist, Robert Brown.

|| See 'Russia in Europe,' &c. vol. i. p. 219; where Brongniart names eleven species from these Russian beds, as belonging to the genus Neuropteris, Odontopteris, Pecopteris, Sphenopteris, and all distinct from any of the forms in the coal.

¶ In this number, 182, are included the two or three plants only of the British magnesian limestone with which M. Göppert is acquainted.

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flora of Germany with that of Russia, M. Göppert finds a very close resemblance between the plants extracted from the underlying Roth-liegende of various German tracts* and those obtained from the strata in Russia, which, as before observed, lie chiefly above the Zechstein. Thus, with the species of the genera Neuropteris, Odontopteris, Callipteris, and Walchia, which have been transmitted from Russia, M. Göppert identifies twenty species of his Silesian and Bohemian collection. Hence the importance of a comparison, which demonstrates the unity of the group over so wide an area.

Again, he observes that certain species of Walchia, particularly Walchia pisiformis, with Callipteris (Neuropteris) conferta, Odontopteris obtusiloba, Pecopteris Gœpperti, Morris and Brongn., Adiantites prisca, Fisch., Gleichenites Gœpperti, Fisch., and Calamites gigas, Brongn., are so widely diffused and so clearly recognized in many countries as of Permian age, that they may truly be considered types (Leit-Pflanzen). To these may be added the Sphenopteris erosa and S. lobata as being also very characteristic.

It is admitted that this flora is, to a great extent, composed of the same families and genera as that of the Carboniferous epoch, and that ferns and Calamites prevailed equally in both periods; yet, when we come to the details, about eight per cent. only of the Permian plants are found to be specifically the same as those of the Carboniferous era; whilst the Psaronites are, according to my eminent friend Dr. Robert Brown, Permian types only.

Again, whilst the Permian flora is generically connected with that of the antecedent but distinct formation, none of its plants save one, the Voltzia heterophylla, is known to have lived on into the succeeding or Triassic formation, or base of the Secondary rocks.

After balancing the whole of the botanical evidence, Göppert concludes, with Brongniart and Morris, that this flora, whether composed of the plants of the Roth-liegende, or those of the Zechstein and *overlying* beds in Russia, *differs from all other fossil floras*, and marks strikingly the close of the paleozoic times, of which it retains the family impress, whilst it is rigidly separated from all the vegetable products of secondary age.

The chief Permian animal remains bear also a strong resemblance to their congeners of the Carboniferous era. When the work on Russia was written, my companions and myself were not aware of more than 166 fossil Permian species, but, by the publication of the works of Geinitz and von Schauroth in Germany†, and of King and Howse in England‡, this number has been increased to 230; still this amount bears a small proportion, when compared with that of the preceding or Carboniferous epoch, in which about 1050 species of animals which have been obtained from the carboniferous formations are already described.

The Permian limestones of England, Ireland, Germany, and Russia, are often rich in the remains of minute animals of the Rhizopodous and Crustacean classes, and which are not, in some respects, far removed from Carboniferous

* Not only those enumerated by my associates and self in our work on Russia, but also specimens transmitted to M. Göppert by Prof. Eichwald and Major Wangenheim v. Qualen.

† Geinitz, Die Versteinerungen des Deutschen Zechsteingebirges, 1848; on the Conularia Hollebeni, Zeits. Deutsch. Geol. Gesells. vol. v. p. 465, and Steinkohl. Sachsens. The memoirs of von Schauroth (Zeits. Deut. Geol. Ges. vol. vi. p. 539; and vol. viii. p. 211) have been published since the issue of the first edition of this work, and have added many new species.

‡ Ann. and Mag. Nat. Hist. vol. xvii., and vol. xix.

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forms. The plate illustrating M. Richter's memoir on the Thuringian Zechstein, in the 7th volume of the Journal of the German Geological Society, presents a characteristic group of these little fossils, very similar in character to those of the British and German limestones of Permian age*. There is, however, a tiny creature not shown there, which was first noticed by Schlotheim under the name of Serpula pusilla. This has lately been shown by Rupert Jones† to be a Rhizopod (as Prof. King had suggested). It occurs in countless numbers in the black Zechstein of the Voigtland, and in the Magnesian Limestone of Sunderland and Tyrone.

The Bryozoa and Corals have the paleozoic type aspect; the small cup-coral, Polycœlia, apparently showing the quadripartite arrangement of the lamellæ characteristic of the cup-corals of the old rocks. The abundant Fenestella retiformis, Foss. 85. f. 3, and Synocladia virgulacea, are also of a type peculiar to the primeval fauna. Crinoids are rare; but there is in England a species of the genus Cidaris, the earliest known representative of the modern sea-urchins‡. The Brachiopods offer many Producti analogous to, but distinct from, those of the Coal period; and about five species, including P. horridus and P. Cancrini, the former being the most common Permian shell in Britain and Germany (Foss. 86. f. 2). These very species, Productus horridus and P. Cancrini, with the Spirifer undulatus and S. cristatus?, have been found in the latitude of Spitzbergen, and are described in detail by de Koninck. Of the genus Spirifer, S. undulatus (f. 1) is the most characteristic, and S. cristatus is supposed to be common to the Carboniferous and Permian rocks. Of the genus Orthis, which prevails so greatly from the Lower Silurian to the Carboniferous inclusive, we here find no trace, with the exception of the O. pelargonata, Schloth.; and according to my colleague, Keyserling, this anomalous species may even form a separate genus. The place of Orthis is possibly taken, in the Permian rocks, by the new genus Strophalosia, King (Orthothrix of Geinitz§, or Aulosteges of Helmersen), which is but rarely found in older strata. Of the few species of Terebratula which are known, two or three are exceedingly abundant, and one, T. elongata of Schlotheim, can scarcely be distinguished from a common carboniferous species. The Athyris Royssii was supposed to be identical with the Devonian and Carboniferous shell. (See 1st Edit. of Siluria, p. 308.) But my friend Keyserling has proved it to be a distinct type, which he has named Terebratula Royssiana, and also figured it in a memoir‖ by himself descriptive of the fossils collected by the botanist Schrenk¶.

* Compare the Rhizopoda and Entomostraca figured and described by Rupert Jones in King's Monog. Pal. Soc. 1848, by Reuss in the Jahresb. Wetterauisch. Ges. 1851, and by Richter, *loc. cit.* Also the Entomostraca from Russia, Keyserling, Schrenk's Reise Arkt. Ural.

† Journ. Geol. Soc. Dublin, vol. vii. p. 78.

‡ The species of Cidaris often quoted from carboniferous rocks, belong, as has been well shown by M'Coy, to a different family. They are now termed *Archæocidaris*. See Ann. Nat. Hist. ser. 2. vol. iii. p. 352. They have lately been found in the Devonian rocks by M. Sandberger.

§ Composed of those species of Productus which have a distinct hinge-area and hinge-teeth.

‖ Paläontologische Bemerkungen von A. Graf Keyserling, in A. G. Schrenk's Reise zu der Samojeder und zum Arktischen Uralgebirge. Zweiter Theil. 1854.

¶ This memoir, prepared in 1848, was not published until 1854, and hence some of the nomenclature has been set aside for other names. The work is highly worthy of consultation. In it the paleontologist will find that the author, who has personally traced the Permian rocks over a vaster northern area than any other individual, enumerates the following fossils, never before described:—Diastopora la-

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The genus Pentamerus, so characteristic of the Silurian epoch, but rare in the Devonian strata, and which has been very seldom found in the Carboniferous rocks of England, has not yet been detected in Permian deposits. In unison, however, with the prevailing law of nature, which, in modifying beings at successive periods, often retained some features of the preceding types, the Pentamerus was represented in the Permian division by the curious terebratuloid shell, named Camarophoria by Professor King, which offers in its internal arrangement an approach to the structure of the Pentamerus. Two of the most frequent Permian shells, indeed, are C. (Terebratula) Schlotheimi, von Buch, and C. superstes, de Verneuil, both figured in the work on Russia, vol. ii. pl. 8. figs. 4, 5. These singular brachiopods also disappeared at the close of the Permian era, and their places were occupied by genera, such as Terebratula or Rhynchonella, which exist even in the present day.

It is worthy of note, that of the seventeen Permian brachiopods which are known in Britain, fifteen occur in the same strata in Germany; whilst among them are certain species, seven in number, which extend their range even to the north-eastern extremity of European Russia.

The following Table, published by the distinguished paleontologist, Mr. T. Davidson, shows this distribution of the Permian Brachiopoda in Britain, Germany, and Russia*.

LIST OF THE BRITISH PERMIAN BRACHIOPODA.

In the Magnesian Limestone of Britain.	Occurring also in Germany.	Russia.
1. Terebratula elongata, Schloth., var. sufflata	*	*
2. Spirifer alata, Schloth.	*	*
3. Spirifer Clannyana, King	*	
4. Spiriferina cristata, Schloth.	*	*
5. Spiriferina multiplicata, Sow.	*	
6. Athyris pectinifera, Sow.	*	*
7. Camarophoria Schlotheimi, von Buch	*	*
8. Camarophoria globulina, Phillips	*	
9. Camarophoria Humbletonensis, Howse	?	
10. Strephorhynchus pelargonatus, Schloth.	*	*
11. Productus horridus, Sow.	*	*
12. Productus latirostratus, Howse	*	
13. Strophalosia Goldfussi, Münster	*	
14. Strophalosia lamellosa, Geinitz, var. Morrisiana ...	*	
15. Crania Kirkbyi, Dav.		
16. Discina Koninckii, Geinitz	*	
17. Lingula Credneri, Geinitz	*	

The annexed woodcut represents a few only of the typical Permian fossils; the figures being about half the natural lineal dimensions.

In the lamellibranchiate shells (the Dimyaria and Monomyaria of most geologists, Strophalosia tholus, Pleurotomaria atomus, and six species of Ostracodes, which require to be compared with the forms described by Rupert Jones, Reuss of Prague, and Richter of Saalfeld. Count Keyserling makes the important observation, that as the Ostracodes are very generally present throughout vast spaces of Russia in beds of Permian rock which contain no other fossil, it is essential to speak of these fossils as singularly characteristic of the formation.

* See Monograph Palæontograph. Soc. 1858.

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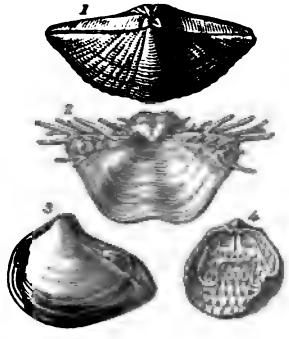
gical works), we note the same diminution of genera and species in reference to deposits of previous eras; and, whilst not less than 288 species are known in the Carboniferous, about 53 only have been obtained in the Permian deposits. Modiola is as yet one of the most characteristic genera; M. Pallasi and M. septifera being common forms. Schizodus, King (*olim* Axinus), is also a characteristic genus: S. obscurus and S. truncatus are from Western Europe; both of them are, however, common in England and Russia. S. Rossicus, de Verneuil, is a Russian species only. The genus Avicula is also abundant; the small spinose

FOSSILS (86). PERMIAN SHELLS.



1. Spirifer undulatus, Sow. 2. Productus horridus, Sow. 3. Schizodus (Axinus) obscurus, Sow. All from the county of Durham.

4. Strophalosia Morrisiana, King. (These species, except, perhaps, the Schizodus, are equally common in Germany as in Britain.)

A. Kazanensis being common in Russia. The Avicula speluncaria of Schlotheim, one of the most characteristic species of Western Europe, was found also by Keyserling, on the banks of the Pinega in the province of Archangel, whilst A. keratophaga and A. antiqua, Münst., are also frequent in the west. Arca tumida, Sowerby, and species of Edmondia, Myacites, &c. are British shells of this age.

"The Gasteropods* appear to have undergone great diminution during the formation of the Permian strata, and to have had great difficulty in accommodating themselves to new conditions. For, if we pass over the seven minute species of Turbo and Rissoa, occurring in one locality near Manchester, the number of Gasteropods known throughout England, Germany, and Russia, in rocks of this age, amounts to but fifteen [*now twenty-one*] species, a number which must appear still more insignificant, when we reflect that as many as 225 species of this class are known in the carboniferous rocks. These fifteen Permian species are almost all new, three only having been able to live on from the Carboniferous to the Permian epoch. The rarity of individual Gasteropods, which are met with in the strata, seems to combine with the paucity of species to make us presume that the causes which were opposed to their free development produced very extensive effects.

"The Cephalopods, which, under the forms of Goniatites, Nautilus, and Orthoceras, were so numerous during the Carboniferous period that 160 species [now many more] have been already described from its strata, were almost entirely annihilated previous to the commencement of the Permian era.

"At least it is remarkable, that, with the exception of a Nautilus, N. Fries-

* The three following paragraphs are extracted from 'Russia in Europe,' vol. i. p. 209.

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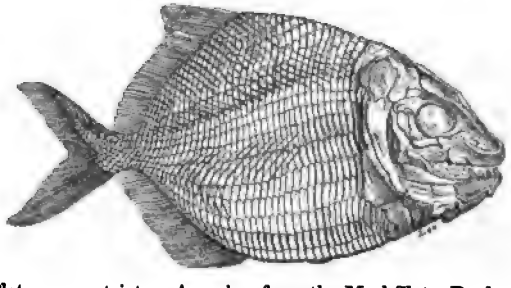
lebeni, Geinitz, no well-characterized cephalopod has been detected in the whole extent of the formation.

"Trilobites are entirely wanting. In the study of the paleozoic succession, we see that the disappearance of this race is regularly announced by a gradual diminution of its numbers during the preceding epochs. Appearing among the earliest forms of life, and having their maximum of development in the Silurian period, Trilobites decrease very sensibly in the Devonian strata, and in the Carboniferous deposits are reduced to some small species, of which Phillipsia and Griffithides are the last expiring forms. And here we are presented with one of those beautiful links in natural history, of which the strata forming the earth's crust have afforded so many proofs. For, with the final extinction of a family destined never more to reappear, its place is taken by an allied crustacean, the Limulus, the earliest form of which was created during the formation of the great coal-fields, and was followed, in our Permian system, by the large and remarkable species as yet peculiar to Russia, the Limulus oculatus (Kutorga). Unlike the trilobite, the Limulus has survived all the numerous revolutions which have followed its creation, and some of its species are co-existent with our own race."

On the whole, therefore, if only a very few species of mollusks are common to the older rocks and the Permian, the latter still retains its connexion with the former through the genera Productus, Spirifer, and Strophalosia, its peculiar group of corals, and of Bryozoa (Fenestellæ, &c.). It is the constant diffusion of many individuals of such forms, which induced my associates and myself to hold firm to the term Permian, as marking the close of primeval life, and in separating it entirely from the Trias and Secondary deposits, in common with which it contains no animal form.

The fossil fishes of this era, of which fifty-three species are known (besides several which are undescribed), all belong, like their precursors in more ancient times, to the division with heterocercal tails; a distinction that becomes evanescent in the succeeding Secondary and Tertiary formations, and in our era is confined to the Shark and Sturgeon families; nearly all other species now living, about 8000 in number, having homocercal tails.

FOSSILS (87). PERMIAN FISH.



Platysomus striatus, Agassiz; from the Marl Slate, Durham.

Of true heterocercal fishes of the Permian group, two figures only are here given, by which the reader will see that the back-bone is prolonged with a bend into the end of the upper lobe of the tail; whilst in the homocercal fishes, or

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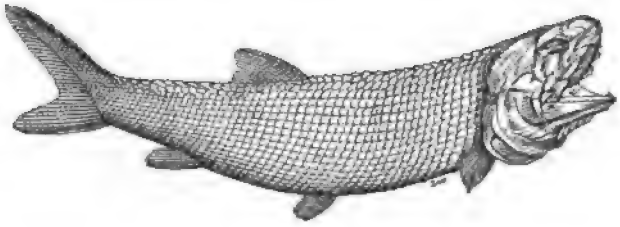
those common in the younger rocks and in the present day, it terminates in the middle, between the equally balanced fins of the tail.

The Palæoniscus, Pygopterus, Cœlacanthus, Pleuracanthus (Xenacanthus), Acanthodes, Acrolepis, and Platysomus, which are the prevailing genera of the Permian era (the same forms being found in England, Germany, and Russia), are also known in the Carboniferous epoch, but all the Permian species are distinct.

FOSSILS (88). PERMIAN FISH.



Palæoniscus Frieslebeni, Agass.; from the Kupfer-schiefer of Mansfeld in Germany.

Lastly, in enumerating the chief features of the Permian fauna, we have to recollect, that whilst a very few reptiles have been found in the next subjacent formation (Carboniferous), and one only in the Devonian, the strata of this newer era contain the relics of Thecodont Saurians, which Owen refers to a higher order of reptiles than any of the older fossils of this family, by showing that they had limbs as well organized as in the living Monitor*. The Protorosaurus, v. Meyer, and Rhopalodon, Fischer, were, according to him, Sauri which occasionally walked on *dry land*.

Struck with the fact of the Permian deposits containing Saurians, Conybeare† and Agassiz thought that the group ought to be placed at the base of the Secondary rocks, which mark the great era of reptiles. But the recent discovery of Sauroid Batrachians in the Carboniferous rocks of Europe and America, and even of one reptile in the Upper Devonian, have satisfied my colleagues and my-

* See Russia in Europe, vol. i. p. 213; and Prof. Owen's description, p. 637, App. My friend Major Wangenheim von Qualen, to whom my associates and myself were much indebted for information respecting the structure of the Permian rocks of Orenburg, has since our visit detected bones of another reptile, which occurs, not, like the remains of the Rhopalodon (Fischer), in the sandstone and conglomerate, but in the limestone (Zechstein) of the formation. The preservation of the head of this animal has enabled M. Eichwald to assign to it the name of Zygosaurus Lucius, and to compare it with the Crocodile. On referring M. Eichwald's description (Bull. Soc. Imp. Nat. Moscou, 1852, No. 4) to Prof. Owen, that celebrated comparative anatomist thus writes to me:—"The characters which M. Eichwald points out in his fossil, as resembling those in the Crocodile, also occur in the fossil skulls of the Labyrinthodont reptiles; and the observation upon the number and comparatively small size of the teeth, in the Permian reptile, would lead to a suspicion that it may really belong to the Labyrinthodont family. All doubt would be removed by an inspection of the occiput of M. Eichwald's fossil: if that part presented a single condyle for articulation with the neck-vertebræ, it would determine the accuracy of his views of its affinities; but if the occiput showed a pair of condyles, it would prove the fossil to be a Sauroid Batrachian."

† My esteemed friend, the late eminent Dean of Asaph, equally distinguished for the broad geological views put forth in his 'Outlines of the Geology of England,' as for his anatomical illustrations of Saurian reptiles (see Trans. Geol. Soc. vol. v. p. 559; and 2nd ser. vol. i. pp. 103 & 381).

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self that this argument was insufficient, and that we were right in being guided by the general facies of the mollusks and plants, and in grouping the Permian (as Phillips had, indeed, previously grouped the Magnesian Limestone) with those antecedent deposits to which it is naturally attached by many links.

The Labyrinthodon Bucklandi (Lloyd), from the neighbourhood of Kenilworth, was found in red sandstones once considered to be of Triassic age, but since assigned to the Permian period*.

In reviewing the few reptiles of the upper paleozoic rocks which have been discovered, we have yet scarcely sufficient materials to enable us to decide on the relative value of such animals in the scale of creation. As far, however, as the above-mentioned evidences go, Professor Owen is of opinion, that the solitary, small reptile of the Upper Old Red Sandstone, found in the vicinity of Elgin (see p. 289), belongs to the Lacertilia, a higher order than the Batrachia, to which the reptiles of the Coal are referred. At the same time, the latter possess characters in their skull and teeth which bring them nearer to the Sauroid fishes than any modern Batrachian.

The same eminent comparative anatomist affirms, that the Thecodonts of the Permian are more nearly allied to the Crocodilians of the Lias, and so to the higher order of reptiles, than any living Monitor; and "just," says he, "as the coal Batrachia are more sauroid, so the Lacertilian Sauroids of the Trias (New Red) are more crocodilian than existing frogs and lizards are." In a letter to myself, from which the above view is derived, he adds, "So far as the reptiles of the Upper Old Red, Coal, and Permian are known, they support the general fact, that the more ancient forms of vertebrata adhered closer to the general archetype of that subkingdom than the more modern forms."

Thus we learn, that in the oldest rocks (Upper Paleozoic), in which they first appear, the reptiles are as wonderful and elaborate in structure as the primeval fishes which accompanied them, or as the corals, crinoids, shells, and crustacea which preceded them during the Silurian or Lower Paleozoic epoch.

In concluding this chapter, it may, indeed, be re-asserted†, that the mass of the organic remains of the Permian group constitute a remnant only of the earlier animals, the various developments of which we have followed in the preceding pages. They exhibit the last of the successive changes which these creatures underwent before their final disappearance. The dwindling away and extinction of many of the types, which were produced and multiplied during the anterior epochs, already announce the end of the long paleozoic period.

In ascending above the highest of the Permian deposits, the geologist takes, indeed, a sudden and final leave of nearly everything

* See Ramsay on the Permian Breccia, Quart. Journ. Geol. Soc. Lond. vol. xi. p. 198.
† See Russia in Europe, vol. i. p. 205.

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in nature to which the words primary, primeval, or paleozoic have been or can be applied.

In short, the two greatest revolutions in the extinct organic world are those which separated the paleozoic rocks from the mesozoic or secondary strata, and the latter from the cainozoic or tertiary and modern deposits.

To the consideration of these two remarkable revolutions in the history of former races, I shall revert in the concluding chapter.

P.S. Having requested my friend Professor Owen to favour me with his views respecting the Permian reptiles, compared with those which preceded and those which came after them, he has kindly enabled me to state, that the characteristic reptiles of the Coal (the Archegosauri) are related to the Batrachians, on one hand, and to the so-called Sauroid Fishes, on the other; and the Labyrinthodont Reptiles of the Trias also show similar alliances. The Thuringian Protorosaurus, however, was decidedly of a higher order of reptiles, having well-organized limbs and vertebræ; it was related to the Monitors of the present day, and was probably of aquatic habits. The Russian Rhopalodon, and the Thecodontosaurus and Palæosaurus of Bristol, belong also to the same well-organized Saurian family; therein resembling the Cladyodon and Belodon of the Trias. All these reptiles, in their thecodont dentition, sub-biconcave vertebræ, double-jointed ribs, well-developed limb-bones, and unguiculate extremities, show as high a grade of organization as the Teleosaurus: in the number (three) of sacral vertebræ they approach the Dinosauria, like which they combine a lacertian form of tooth and lacertian type of pectoral arch with the above crocodilian characters. The Rhynchosaurus of the New Red Sandstone participates, with the Thecodonts of the Bristol conglomerate, in the peculiar moniliform spinal canal.

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CHAPTER XIV.

GENERAL VIEW OF THE SILURIAN, DEVONIAN, AND CARBONIFEROUS ROCKS OF SCANDINAVIA AND RUSSIA.

COMPLETING in the last chapter a notice of the Paleozoic rocks, in ascending order, by a sketch of the Permian deposits, special references were made to Russia, whence the name 'Permian' was taken, and to Germany, where the different strata of the group had been so long studied. Let us now endeavour to delineate in broad outline the continental equivalents of the Silurian, Devonian, and Carboniferous rocks of Britain.

Throughout large portions of Western Europe, *i. e.* Germany, France, Spain, and Portugal, these paleozoic deposits have been, in some tracts, so much metamorphosed and crystallized, in others so penetrated by igneous rocks, and even so dislocated, that notwithstanding the researches of many good geologists and mineralogists, the task of reducing them to a normal order of succession is far from being completed. Deferring, therefore, such explanation of these complicated regions as may be practicable, let us first take a view of the succession of primeval life in Scandinavia and Russia in Europe, where, on the contrary, the series of the older fossil-bearing sediments is exhibited, over very wide areas, in the clearest and most symmetrical order, and for the most part uninterrupted by the intrusion of igneous or volcanic rocks*.

* The limits of this work do not permit any attempt to delineate the mineral composition of the Ural Mountains, except to indicate, by the way, how clearly they exhibit the metamorphism of the paleozoic deposits of Russia in Europe. An acquaintance with many of their natural productions must be sought in the works of authors, from the time of Pallas to the days of the most illustrious of all travellers, Humboldt, who explored these regions accompanied by his friends Gustaf Rose and Ehrenberg, and extended the lights of physical science to the frontiers of China. Besides the 'Reise nach dem Ural, dem Altai,' &c., of those authors, the reader will find a great body of information in the 'Archiv für wissenschaftliche Kunde von Russland,' conducted by M. Adolf Ermann, the explorer of North-eastern Siberia and Kamtschatka. Among the authors who have written on the mineral structure of Siberia, Helmersen and Hoffmann also stand out conspicuously, as will be seen by those who consult their publications in the 'Annuaire des Mines de Russie.' The splendid work also of M. Pierre de Tchihatcheff, on the Altai Mountains, and many others would have to be noticed; but as this volume is chiefly an outline of the nature and succession of the older sediments, I cannot here expatiate upon the labours of many of my contemporaries.

In the work 'Russia and the Ural

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In Scandinavia and Lapland, ancient crystalline rocks occupying the chief mass of that territory, and consisting to a great extent of granite and gneiss, with many varieties of schistose and quartzose strata, often metalliferous, in which nothing organic has been discovered, are covered at intervals by true representatives of the Silurian rocks.

The inferior beds, which are charged with animal remains, are clearly the equivalents of the lowest Silurian strata of the British Isles, Bohemia, and other countries.

The first of the following diagrams represents the succession of Lower Silurian deposits from a base of crystalline gneiss and associated strata near Kinnekulle in Sweden*.

LOWER SILURIAN STRATA OF SWEDEN REPOSING ON GNEISS.

(From 'Russia in Europe,' p. 15.)

d. Black graptolite schists. *c.* Orthoceratite limestone. *b.* Alum slates. *a.* Lowest or fucoid sandstone.

gn. Gneiss. *t.* Trap or eruptive greenstone. *bl.* Erratic blocks.

In other parts of Sweden, as near the Billingen Hills, the two lower strata, *a*, *b*, of the above section are seen to rest upon granitic rocks without any intervening crystalline schists. In such cases the lowest sandstone, which is used as a millstone, is simply a re-aggregated granite,

Mountains,' references are given to the authors, both anterior and contemporary, who have illustrated the older sedimentary deposits and their fossils in the Russian Empire. Special allusion is there made to the first, and a very able, attempt at the construction of a geological map of Russia by the Hon. W. Fox Strangways, and to his original sketch of the environs of St. Petersburg, in Trans. Geol. Soc. Lond. 1 ser. vol. v. p. 392. References are of course also made to the original work of Pander on the fossils of the same district, and to Eichwald's 'Système Silurien de l'Esthonie.' Since the publication of our work, my friends and self have been gratified by seeing it translated (1849) into the Russian language by Colonel Osersky, who has added some important data from his own observation and other sources, including corrections of our general geological map.

* A detailed geological map, including all the crystalline and metalliferous rocks of Sweden, has for some time been in preparation, but is not yet published. This task was undertaken by MM. Forsells, Erdmann, Franzen, and Troilius, but abandoned. M. Erdmann, who has lately visited England, has now taken it up by authority, and will, I trust, complete this work.

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the *arkose* of Brongniart; the materials being derived from the subjacent rock.

OLDEST SILURIAN STRATA OF SWEDEN RESTING ON GRANITE.
(From 'Russia in Europe,' p. 16.)

b. Alum schist. *a*. Fucoid sandstone. *a'*. Arkose. *gr*. Granite.

Now, whether the subjacent rocks be composed of granite, granitic gneiss, or flinty slates, quartzose or other crystalline masses, the fundamental strata in which any traces of former life can be detected are sandstones and schists, which stand in the place of the lower fossiliferous beds of Britain, and of that primordial zone in Bohemia which will presently be noticed. The bottom beds contain fucoids, or casts of seaweeds only; but the lowest band of schist is well characterized by its fossils in several parts of Sweden, and particularly at Andrarum, where it contains trilobites of the genera Paradoxides, Olenus, Conocephalus, Agnostus, &c.

The limestones which next overlie (*c*, of the section at p. 365), and which abound in Orthidæ, large Orthoceratites, Trilobites, and Cystideæ, are distinctly the equivalent of the British Llandeilo formation of schists, flags, and limestone, &c. Above these, but connected with them, is a considerable mass of shale or schist, chiefly characterized by Graptolites, and this is covered by other limestones, which in Gothland are profusely charged with very many of the same species of shells and corals as are found in the limestones of Wenlock and Dudley. The whole of this series is capped, in the south of Gothland, by certain sandy strata, which are supposed to be meagre equivalents of the Ludlow rocks*.

Whilst, however, the organic remains of the Silurian rocks of Sweden have been elaborately and ably described by various authors†, there is nowhere to be seen, in any one tract of that kingdom, the same concen-

* See details of this succession, by Murchison and de Verneuil, Quart. Journ. Geol. Soc. Lond. vol. iii. p. 1.

† See 'Palæontologia Suecica,' pt. 1. In this brief sketch, no justice can be done to the numerous works on the rocks and fossils of Sweden and Norway; countries which, from the time of Linnæus to the present day, have contributed so much to the progress of natural history. In the memoirs of Nilsson of our time, in those of Wahlenberg and Gyllenberg of past years, and in the works of Lovén and Angelin, which have recently appeared, the fossil organic remains have received much illustration in addition to the knowledge formerly communicated in the 'Lethæa Suecica' (1837) of Hisinger. The 'Geea Norvegica' of Keilhau has great merit for its description of the lithological character of the various Norwegian rocks. But the work which has completely worked out the precise relation of the component parts of the Silurian rocks of Norway is that of M. Kjerulf. It is from this publication that all the fresh data in this new edition of 'Siluria' are derived, which determine with so much exactness the similarity of the English and Norwegian Silurians.

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trated succession of all these strata from their base upwards, or one natural section so clearly connecting the Lower and Upper Silurian, as is exhibited in Norway, and particularly in the territory of Christiania. There, as formerly described by myself, various strata, clearly divisible into 'Lower' and 'Upper' Silurian through their characteristic fossils, are regularly exhibited in a very small compass in the Steensfiord, between the river Drammen and the Krokleven, to the west of Christiania, where their uppermost member is conformably overlaid by a great accumulation of Old Red Sandstone with conglomerate, as expressed in the two following diagrams*, prepared on the spot by myself in 1844.

SUCCESSION IN NORWAY. (From 'Russia in Europe,' p. 10.)

o. Azoic crystalline rocks. *a*. Lower sandstones, schists, limestone, and flags. *b*. Limestone, with Pentameri. *c*. Coralline limestone (Wenlock). *d*. Calcareous flagstones (Ludlow). *e*. Old Red Sandstone. (*p*. Rhombic porphyry. *t*. Other eruptive rocks.)

The same strata prevail in the Bay of Christiania; but there they are at many points contorted and penetrated by syenites, greenstones, and hypersthenic rocks, whereby the lower alum schists are here and there crystallized, and the limestone, *b*, converted into marble. The next section (a continuation to the east of the preceding diagram) explains their relations, and shows how the undulating and broken masses, regaining their order, fold over and dip under a great mass of Old Red Sandstone, the eastern extremity only of which is represented in the preceding diagram.

e. Old Red Sandstone. *d*. Calcareous flagstones. *c*. Coralline limestone and shale (Wenlock), beautifully exposed in many islands of the bay. *b*. Limestone, in parts a marble (Paradis-backen). *a*. Lower Silurian schists, &c., in parts altered. *o*. Azoic gneiss. *t*. Various eruptive rocks. (The *t* of this section represents most of the intrusive rocks, whether syenites, greenstones, porphyries, or younger granites, which have been forced through the strata. *p* refers to the large rhombic porphyry on the summit of the plateau.)

Having now adverted to the sections of this tract which I made in 1844, when I first placed the older fossiliferous strata of Norway in parallel with the

* For the particulars of these phenomena, consult 'Russia in Europe,' vol. i. p. 10 *et seq.*, and Quart. Journ. Geol. Soc. Lond. vol. i. p. 467 (Murchison 'On the Paleozoic Deposits of Scandinavia, &c., and their Relations to Azoic or more Recent Crystalline Rocks'), 1845.

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Fig. 1.—General Section of the Silurian Rocks in Norway.

Fig. 2.—Section of a part of Ladegaards-ö.

N.N.W. Beston Kilen. S.S.E.

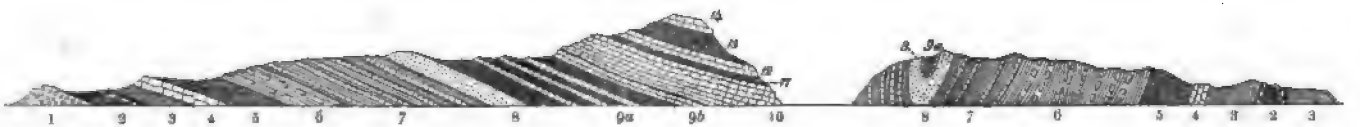

Fig. 3.—Section from the Lower Silurian (Caradoc) Rocks of Ormö to the Lower Ludlow Rocks of Malmö.

W. Ormö. Malmö (130–150 feet). E.

Lingula Flags.
3. Lower Graptolite schists.
2. Alum schists.
1. Quartzite (Cambrian).

Caradoc or Bala.
8. Calcareous sandstone.
7. Calcareous and argillaceous flagstones.
6. Orthoceratite limestone and Lower Encrinal schists.

Llandeilo Rocks.
5. Upper Graptolite schists.
4. Lower Orthoceratite limestone.

Upper Silurian.
14. Upper Malmö limestone.
13. Upper Graptolite schists.
12. Lower Malmö or Upper Orthoceratite limestone.

Llandovery Rocks.
11. Upper Encrinal schists.
10. Coral limestone.
9b. Pentamerus limestone.
9a. Lower argillaceous schists.

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Silurian and Devonian rocks of my own country, and showed that the thousands of feet of the Silurian strata of Britain are fully represented, as respects their fossils, by the hundreds of feet only which exist in Norway, it is most gratifying to find my inferences are proved to be true by the recent detailed labours of M. Theodor Kjerulf*.

Dividing the whole Silurian series of Norway into the three physical groups of Oslo, Oscarskal, and Malmö, M. Kjerulf has recognized fourteen distinct fossiliferous bands, as exhibited in the opposite sections.

The same zealous author has published a work in which he classifies the two great sedimentary deposits of South Norway, the one exhibiting a vast development of unfossiliferous rocks, to which he applies the name of Cambrian,—the other being the overlying Silurian rocks, of which he describes each stratum with its respective fossils from the alum shales upwards.

In referring to the section, fig. 1, we see, that the alum schists (2) with bituminous limestone rest upon unfossiliferous and siliceous grauwacke (1), the equivalent of the upper part of the Longmynd (Cambrian) of Britain. In No. 2, the lowest zone in which intelligible fossils have been detected in Scandinavia, there are found small graptolites, the Graptopora† flabelliformis (Gorgonia, Eichwald), several species of Lingula, including one like L. Davisii, a horny shell nearly allied to Obolus Apollinis, Agnostus pisiformis, Olenus scarabæoides, Boeck, Olenus (Trilobites) latus, Boeck (Eurycare latum, Angelin), Olenus (Trilobites) alatus, Boeck (Sphærophthalmus alatus, Angelin), Olenus (Dalm.) gibbosus, Wahl., Asaphus grandis, and Trilobites pusillus, Sars.

This zone (2), being unquestionably the same as the Regiones A, B, of Angelin in Sweden‡, is manifestly the northern equivalent of the "primordial zone" of Barrande in the Silurian basin of Bohemia, and of the Stiper Stones and Lingula schists of Britain; and, though only 150 feet thick, contains Graptopora flabelliformis mixed with Lingula as in our own country, and with them the Agnostus pisiformis and the graptolite, Didymograpsus geminus, as well as the Silurian brachiopod, Orthis calligramma. The last three species occur also in the Llandeilo zone of the Silurian region of Britain. In other words, we thus see clearly that, in extending our survey, *it is impracticable in general classification to separate the Lingula flags, or "Zone Primordiale," from the other Lower Silurian rocks.*

The next mass of schists (3, 4, 5), with an intermediate limestone, bears a close analogy to its congener in Britain, by ushering in with it a profusion of species, and well represents the Llandeilo formation. Amongst its fossils are the graptolites, Diplograpsus pristis, D. folium, D. teretiusculus, Graptolithus sagittarius, and the shells, Orthis calligramma, O. elegantula (O. parva, de Vern.), O. flabellulum (?), Bellerophon bilobatus, B. acutus, Orthoceras duplex, O. annulatum, Lituites cornu-arietis, with Phacops conophthalmus (Asaphus Powisii, Sil. Syst.), and many other trilobites of species peculiar to Sweden, but all belonging to the Lower Silurian genera, Asaphus, Ogygia, Trinucleus, Olenus, &c.

The group (6, 7) consisting of calcareous and argillaceous flags, intermediate

* Das Christiania Silur-Becken, 1855.

† Proposed by Mr. Salter in 1857 (see p. 47) for this curious form, which seems to connect the Fenestellidæ with the Graptolites. It is, however, the Phyllograpsus, Angelin, MS. Rep. of Amer. Assoc. for 1857, Montreal.

‡ See M. Barrande's lucid memoir, 'Parallèle entre les Dépôts de Bohème et de Scandinavie,' 1856.

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Orthoceratite limestone, and lower Encrinal schists, though intimately connected by many forms with the underlying divisions, is yet characterized by many other fossils, which enable us to refer it to the true Caradoc or Bala formation, as defined in the fourth chapter of this work.

These fossils are: Orthis calligramma, O. testudinaria, O. Pecten, Leptæna sericea, Lingula attenuata, Bellerophon bilobatus, B. acutus, Conularia quadrisulcata, and probably C. Sowerbyi, with other species; Orthoceras duplex, O. gigas, O. dimidiatum, O. distans, and O. annulatum; the last three being Upper Silurian forms in Britain. The other fossils of Lower Silurian age are: Lituites cornu-arietis, Trocholites anguiformis, Euomphalus and Turbo several species, including Euomphalus alatus, Hisinger?; with Echinosphærites Aurantium, Tentaculites Anglicus (annulatus, Sil. Syst.), with the well-known trilobites, Asaphus expansus, Trinucleus concentricus (Caractaci, Sil. Syst., var.), T. seticornis, Ampyx nasutus, Ogygia, Calymene Blumenbachii (var. pulchella), and the Phacops macroura, Sjogren, which closely resembles the P. truncato-caudatus of the British Caradoc formation. The corals are: Stenopora fibrosa and its variety Lycoperdon, with species of Turbinolopsis (Petraia), &c.

The calcareous sandstone (No. 8, sections) would seem, from its organic remains, to constitute the commencement of a transition from the Lower to the Upper Silurian rocks, such as is seen in the Lower Llandovery rocks of South Wales. Thus, with the Orthis testudinaria and O. zonata, Dalm., and Patella antiquissima, His., occurs a characteristic Lower Llandovery species, Rhynchonella angustifrons, M'Coy, and many large smooth Pentameri of species not yet named. Here are some associated fossils which are also commonly found in the Upper Silurian rocks of Britain. These are: Strophomena depressa, Euomphalus sculptus, Phragmoceras? (Cyrtoceras) ventricosum, Encrinurus punctatus, Actinocrinus moniliformis, Favosites alveolaris, Heliolites megastoma, Halysites catenularius, Cyathophyllum turbinatum, &c.

In speaking of the characters of the fossils of this zone, it is to be observed, that the characteristic Lower Silurian trilobites have already disappeared *.

The argillaceous schists with calcareous flags (No. 9*a*) obviously represent also a part of that intermediate group connecting the Lower and Upper Silurian, to which I have now assigned the name of "Llandovery rocks." For, in these beds certain species of Pentameri are first met with, whilst the overlying limestone (9*b*) is, as in Britain, charged with the Pentamerus oblongus, and forms in both countries a clear horizon.

The fossils are: Fenestella asimilis, Alveolites (Millepora) repens, Cœnites intertextus, Ptilodictya (Eschara) Scalpellum, Halysites catenularius, Orthis calligramma, O. elegantula, O. testudinaria, O. Pecten, O. zonata, Dalm., O. lamellosa, Strophomena depressa, Leptæna transversalis, Orthis (Spirifer) insularis, O. biforata (Spirifer Lynx, Sp. dentatus, Atrypa crassicostis, &c.), O. biloba (Sp. sinuatus, von Buch), Cyrtia trapezoidalis, Trigonotreta compressa, Pentamerus (Atrypa) galeatus, P. Lens, P. lævis, Atrypa reticularis, Linn., A. Prunum, A. tumida, and A. aspera, Dalm., Euomphalus funatus, E. sculptus, Acroculia Haliotis, Calymene Blumenbachii, Encrinurus punctatus, Ampyx, Acidaspis, and the Trilobites (Proetus?) elliptifrons of Esmark, T. elegans, Sars, &c.

* Some of these corals and shells in Britain range from the Caradoc formation to the base of the Ludlow rocks.

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The band with Pentamerus oblongus is at once followed by another limestone (No. 10) highly charged with corals and crinoids, and which evidently characterizes the mass of the Wenlock limestone. It is, however, important to remark, that, with many corals, the Euomphalus sculptus, E. carinatus, and even the Orthoceras annulatum and O. Ibex, Sil. Syst., we again meet with the Pentamerus oblongus and P. lævis of the subjacent band, thus linking together, still better than in England, these beds with the inferior strata, and showing a higher vertical range of the above species of Pentamerus than is known in England, where they never rise into the Wenlock formation. The list of fossils includes Ptilodictya lanceolata, P. (Eschara) Scalpellum, and the corals, Cyathophyllum turbinatum, Goldf., Ptychophyllum patellatum, several species of Heliolites, and several forms noticed in the underlying strata, with Sarcinula organum, a species of Lower Silurian age in Britain. The prevailing Encrinite is Actinocrinus moniliformis, Goldf.; whilst the Cornulites serpularius, Sil. Syst., is accompanied by the following shells, Rhynchonella borealis (Ter. plicatella, Dalm.), Euomphalus carinatus, E. sculptus, and other spiral forms, Orthoceras Ibex, O. annulatum, with the Pentamerus conchidium and the other species above noted. The Encrinal schists (11) and Upper Orthoceratite limestone (12), the Upper Graptolite marls (13) and the Upper Malmö limestone (14), with the schists and marls of Overland, Opsahl, Noes, Krogsand, &c., represent other members of the Upper Silurian, as far as the lower and middle members of the Ludlow rocks inclusive—the Upper Ludlow rock not being well represented by fossils.

Whilst the ordinary Wenlock corals seem to pervade all the last-named rocks, their lower members, or the Encrinal schists and Orthoceras limestone, characterized by large Orthoceratites with central siphuncles, may, however, be supposed to represent the Lower Ludlow, the more so, as they contain Gomphoceras pyriforme, Sil. Syst. In the overlying shales, Graptolites priodon (Ludensis) abounds; but it is to be noted that this zoophyte is associated with the Retiolites Geinitzianus, Barr., and Cyathocrinus rugosus, both of Wenlock age, in Britain, the former even pointing to the very base of the formation.

Even the upper limestones, schists, and shales, as seen at Malmö and the places above cited, are still charged with some corals and crinoids, known in England in the Wenlock formation only, including among the latter, Eucalyptocrinus decorus and Crotalocrinus (Cyathocrinus) rugosus. On the other hand, here are also found some of the typical species of the Ludlow rocks, viz. Chonetes (Leptæna) lata, Rhynchonella Wilsoni, R. navicula, Turbo corallii, Pterinea retroflexa, Orthoceras Ibex, &c.

In my own rapid survey of the environs of Christiania, as formerly explained to the Geological Society, I could not, any more than M. Kjerulf, detect fossils indicative of the uppermost Ludlow rock, though I then pointed out a conformable passage upwards from the grey Silurian rocks into an overlying red sandstone. In some parts of Sweden, however, and on another occasion, my coadjutor M. de Verneuil and myself detected organic remains in strata which must, we thought, represent the Upper Ludlow, and even a transition into the Devonian. Thus, in Scania we found true Upper Ludlow fossils in red flaggy sandstones which Forchhammer had classed as Old Red Sandstone*.

Again, in proceeding from the northern and central parts of Gothland, which

* Quart. Journ. Geol. Soc. vol. iii. p. 34.

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are occupied by the Wenlock limestone, we at length reached beds of a sandy and marly character, in which some of the species above mentioned, including the Pterinea retroflexa, Chonetes lata, and Turbo corallii, were collocated with the Rhynchonella (Terebratula) nucula, Orthonota retusa, Murchisonia articulata, and Beyrichia tuberculata, all fossils of the Upper Ludlow rock.

The detailed sections of the strata in the environs of Christiania are most valuable in demonstrating, by comparison, that the Silurian rocks of Norway are, from their base upwards, the true equivalents of those of Britain; and also in showing that the alum schists, like the Lingula flags and Stiper Stones, form the natural-history base of the Silurian system. The sections also demonstrate that from this base to the uppermost beds, these zones (in all occupying less than 2000 feet in vertical dimensions) represent the whole of the vastly expanded British series, and constitute one conformable and natural system, whether viewed physically or zoologically*.

In addition to the clear order of superposition of the various Silurian rocks and their identification by fossils, M. Kjerulf has further shown, how different members of the series have been here and there metamorphosed into crystalline gneiss. The numerous points at which the sedimentary formations have been pierced by eruptive rocks, long ago offered to Professor Forchhammer and myself sufficient explanation of such conversions†.

This subject has, indeed, been since worked out in some detail by Mr. David Forbes, whose residence at Christiania has enabled him to contribute satisfactory information, which clearly demonstrates the conversion of sedimentary Silurian strata into crystalline rocks replete with simple minerals‡.

To resume the history of succession. The primordial fauna of Scandinavia, which I long ago characterized as "the earliest zone of recognizable life," consists, in its lowest stage, of fucoids only. The next zone contains the graptolites, shells, and trilobites before alluded to, some of which are identical with fossils of our Lingula flags of Britain. Its trilobites have been elaborately described by M. Angelin§, who has added much to our acquaintance with these fossils. Among the crustacea of these beds (Regiones A, B, of Angelin), we recognize in Sweden several of the genera which characterize some of the lowest of the fossiliferous beds of Britain. The most plentiful of these crustaceans are Agnostus pisiformis and many species of Olenus, of which last-named genus some species also occur in the lowest schists of our Malvern Hills.

Then, the Swedish Regiones C and D of Angelin are, as in Norway, nothing more, as respects their fossils, than masses of Lower Silurian rocks (Llandeilo and Caradoc), as described in England and Wales, and which reappear in great force in the Bay of Christiania, Norway. They are specially identified by the abundance of trilobites, of the same genera

* Judging from a collection recently transmitted by M. Kjerulf, and which has been examined by Mr. Salter, the specific identification with the British forms may be for the most part depended upon.

† Quart. Journ. Geol. Soc. vol. i. p. 470, &c., and Russia in Europe, vol. i. p. 14, *note*.

‡ Quart. Journ. Geol. Soc. vol. xii. p. 166, &c.

§ Palæontologia Suecica, pt. 1, 1852.

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as our British strata of this age, viz. Asaphus, Ogygia, Remopleurides, Trinucleus, Illænus, Ampyx, &c. Many species of trilobites and mollusks of the two countries are identical, as shown by the preceding details.

Having examined these Lower Silurian rocks over various tracts of Sweden and Norway, I can assure geologists that, rich as they are in fossils—so rich that they have enabled M. Barrande, as will soon be seen, to parallel every one of their stages, from the lowest upwards, with the primordial and succeeding zones of Bohemia—the whole of the Lower Silurian of Scandinavia never much exceeds in vertical thickness about 1200 feet! And yet this mass is as complete in the development of life, as the 30,000 feet of strata of the same age in Britain, which have been so much expanded by intercalations of igneous matter! Nay, the general succession is essentially the same as in our islands. For, the Lower Silurian of Sweden and Norway is conformably overlaid by a zone charged with Pentamerus oblongus, and passes up into shales and limestones, which completely represent the Upper Silurian, particularly the Wenlock formation.

And here, in respect to nomenclature, I may observe, that the geologist who should seek to separate the Lower Silurian of Sweden and Norway from the Upper, and call the higher part only Silurian, would make a distinction which could not be followed out upon any map. For, these two groups are there often exhibited, as in the preceding sections, in such frequent undulations, as to constitute one united mass of very small dimensions, *all the strata of which have a community of aspect, and maintain a perfect parallelism to each other.*

The remarkable resemblance of the chief limestones of Gothland, and certain isles in the Bay of Christiania, to those of Wenlock and Dudley, a very great number of the fossils being common to Scandinavia and Britain, is well known to all geologists and collectors.

Silurian Rocks of Russia.—Following these ancient deposits into the Baltic provinces of Russia, and beginning our examination of them in the environs of St. Petersburg, where their lowest beds are exposed, we find that the hard crystalline rocks of Scandinavia, and thence extending into Finland, have subsided beneath the sea-level, and that we can nowhere observe that junction which is so clearly observed in Norway and Sweden between the lowest Silurian rock, and the masses which were formed before it.

Ranging from the banks of the river Neva at the Imperial metropolis, to the cliffs west of Narva, the lowest visible strata are composed of bluish or greenish shale (the blue clay of Russian geologists), though, in sinking the piles for the support of the new granite bridge at St. Petersburg, and in other subterranean works, courses of incoherent sand have also been met with in it. This clay, although as soft as that of tertiary age in and around London, and so plastic as to be used even by sculptors

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for modelling, is clearly of the same age as some of the oldest strata described in Sweden and Norway, or as the much harder and more crystalline lowest Silurian slates of Wales—so entirely have these venerable Russian strata been exempted from the influence of change.

For a long time no other organic remains were detected in this lower blue clay or shale, save the supposed fucoidal remains which Pander had termed Platydolenites; but recently that author has detected in this matrix, traces of fossil remains which he has not yet described, as well as rare examples of those extremely minute microscopic bodies which he considers to be fishes' teeth, and terms Conodonts.

The lower clay or shale is followed upwards by sandy beds in parts so coherent, particularly when cemented by oxide of iron or a little calcareous matter, as to form a sandstone, occasionally a calcareous grit, on which the castle of Narva stands. On the banks of the rivers Ishora, Tosna, and Siass, tributaries of the Neva, these sandy strata are interlaminated by thin courses of shale approaching to impure fuller's earth, the sandier parts of which are intermixed with green grains, occasionally containing small concretions. In these layers Pander has found several of his microscopic Conodonts. But the organic bodies which specially characterize this band are the Obolus Apollinis, Eichw. (the Ungulite of Pander), Orbicula Buchii, and O. reversa, de Vern., and some rarer shells termed Siphonotreta and Acrotreta. Of these, however, the little horny brachiopod, the Obolus or Ungulite, is so much more abundant than any other fossil, as to have induced Pander to give to the rock the name of Ungulite grit.

This Ungulite grit is overlaid by a course of dark-coloured schist, which contains graptolites, and is often bituminous, particularly in Esthonia, where it has even been extracted for fuel.

The chief or Orthoceratite limestone—the Pleta, which follows, is characterized at its base by sandy calcareous beds containing a profusion of those dark green grains which are here and there apparent in the subjacent strata, and which are supposed to be the debris of ancient augitic rocks of Finland (see 'Russia in Europe,' p. 28*). In lithological aspect, however, these lower calcareous beds usually so resemble the Craie chloritée of the French, or the green varieties of the Upper Greensand of England, that, when mineral characters alone guided geological classification, they were even supposed to belong to the cretaceous system. That misapprehension was, however, long ago removed by the works of Pander and Strangways. Separated by way-boards of greenish-grey or reddish shale, these green calcareous beds are surmounted by the earthy, grey, flat-bedded limestone, which, occupying the hills of Czarskoe Celo and Duderhof south of St. Petersburg, ranges westward into Esthonia, and is the chief fossiliferous band of the Lower Silurian rocks. It is in the green sandy beds which underlie this rock that the greater number

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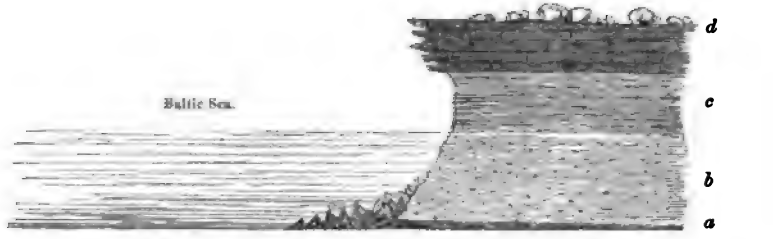
of the bodies called Conodonts by Pander have been found, though these ambiguous little things have also been detected by that author in the overlying mass of the great Lower Silurian limestone, in parts of the Upper Silurian and Devonian rocks, and even in the Carboniferous limestone!* In the cliffs of the Gulf of Bothnia, it appears in relation to the inferior strata as in the annexed woodcut:—

LOWER SILURIAN ROCKS.—CLIFFS NEAR WAIWARA.



a. Lower shale, obscured by fallen fragments of rock and ice-borne Scandinavian blocks. *b*. Ungulite grit. *c*. Argillaceous schist, with graptolites (Phyllograpsus). *d*. Orthoceratite limestone (covered by granite blocks which were transported from Sweden during the glacial period: 'Russia in Europe,' vol. i. pp. 34, 511, *et seq.*).

* In his work on the Silurian fishes of the Baltic provinces of Russia (Monographie der fossilen Fische der Silurischen Systems der Russisch-Baltischen Gouvernements, St. Petersburg, 1856), my eminent colleague of the Imperial Academy of St. Petersburg has endeavoured to prove that these microscopic bodies (smaller in fact than the minutest pin's head) are the teeth of fishes, and terms them Conodonts.

In perusing M. Pander's work, the reader will perceive how fairly and ingenuously the author treats every branch of this curious and recondite inquiry, when he says, that, as the Conodonts are never found in connexion with the hinder part of the animal, nothing can be known of their position or attachment, and we can only assume "that, like the teeth of Cyclostoma and the Squalidæ, they were fixed to the mucous membrane of the throat or mouth, but whether to the jaw, the lip, or the tongue is uncertain."

Admitting the *à-priori* improbability of fishes' teeth being found in the Lower Silurian rocks, and that there is little or no analogy between the structure of these Conodonts and that of ordinary fishes' teeth (pp. 8 and 9), he looks for a similar lamellar structure in other hard parts of fish, and finds it in the scales of Ganoid fishes, and so proceeds to sustain his views as to the piscine nature of these bodies. He also points out, that the teeth of Clupea, Perca, Salmo, and other Teleostian fishes, though lamellar, like the Conodonts, are, like them, equally devoid of dentinal tubuli.

The naturalists, including M. Barrande, Dr. Carpenter, and Mr. Quekett, who had examined these little specks when my first edition was issued, could not detect, even when placed under the microscope, any bony structure; and it was then suggested that they might prove to be the hard ends of the lateral appendages of a crustacean (trilobite).

Admitting the ability with which M. Pander has met the objections to his view which I formerly urged, I still remain of opinion that it is not yet proved that the Conodonts belong to fishes. Anxious, however, to ascertain the whole truth, I have submitted some specimens recently sent to me at my request by M. Pander, to the scrutiny of my colleague Professor Huxley, who says, that, although they exhibit neither bony nor dentinal structure, they might belong either to Myxinoid fishes or Mollusca; and as he is now sifting the evidence in favour of, and against, both these alternatives, the conclusions, if any, at which he may arrive will be given in the Appendix.

In the meantime let me say, that whilst in his work M. Pander states that these bodies are chiefly composed of almost pure carbonate of lime, he now informs me by letter, that his view of the dental nature of

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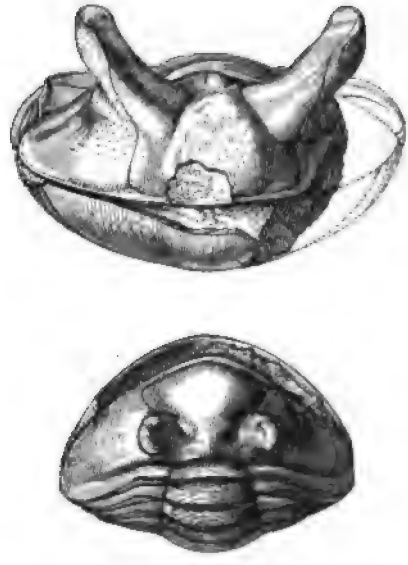
These lower limestones, which constitute the chief members of the Lower Silurian of Russia, are filled, as in Scandinavia, with a profusion of Trilobites, Orthidæ, large Orthoceratites, univalve shells, and Cystideæ, characteristic of this age. One only—and the most remarkable of the

FOSSILS (89). ASAPHUS EXPANSUS, var. CORNUTUS, FROM THE PLETA LIMESTONE. (From 'Russia and the Ural Mountains,' vol. i. p. 37.)



these Conodonts has been further confirmed by chemical analysis, which shows that their chief component is *phosphate of lime*; and Dr. Percy has confirmed that result by a second analysis. But the Obolus or Ungulite of these Russian beds may contain phosphate of lime, as that mineral is known to exist in the Lingula. Again, Troschel informs us that phosphate of lime is a constituent of the lingual teeth of Dolium, Helix, and Patella. (Das Gebiss der Schnecken, p. 29.) Having further ascertained that the long and rounded large bodies in the same beds, with an internal cavity, which not unfrequently occur in the lowest Russian strata, and are charged with green grains, also contain phosphate of lime, M. Pander is led to believe that these bodies must be the coprolites of the fishes whose teeth he has described as Conodonts. Now, even if my belief, that the phosphatic nodules were derived from some of the mollusca which are known to prevail in these Russian strata, be not admitted, we have no occasion to refer these round bodies to coprolites simply because they contain phosphate of lime; since there are examples of that substance occurring in large rock-masses and veinstones in Spain and elsewhere, in which the mineral could not possibly have been derived from bony animals, and must have proceeded from deep-seated sources.

Reserving any further details respecting these microscopic Conodonts, I may now state, that I have been strongly confirmed in my bias against their pertaining to Vertebrata, by looking at the figure of the lingual dentition of the Cuttle-fish as depicted by Woodward in his excellent 'Manual of the Mollusca' (p. 448), in which he extends the line of inquiry opened out by Lovén; for in that figure we see, in the prismatic form of the base, and the claw-shape of the lateral *uncini*, a remarkable resemblance to the Conodonts of Pander; and we know that Cephalopoda abounded in Lower Silurian times.

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trilobites—is here represented (Foss. 89), viz. the singular variety *cornutus* of the common Asaphus expansus of Wahlenberg.

Among the other characteristic fossils may be cited, Amphion Fischeri, Eichw., Illænus crassicauda, Dalm., Ampyx nasutus, Dalm., Cybele verrucosa, Dalm., Orthis calligramma (Pl. 5. f. 7,8,9), O. biforata, Schloth., Orthoceras duplex, Wahl., and many Cystideans, of which Echinosphærites Aurantium is the type.

Here, laying before the reader a reduced sketch of the very character-

FOSSILS (90). ORTHOCERAS DUPLEX, WAHLENBERG.

A characteristic Russian and Scandinavian fossil.

istic and large Orthoceratite of the Lower Silurian rocks of Scandinavia and Russia (Foss. 90), we must refer to the works of Pander, of Eichwald*, and of myself and colleagues, for a full description of the fossils.

In proceeding westwards from the Government of St. Petersburg into Esthonia, the calcareous flagstones (Pleta) are underlaid by a bituminous and inflammable shale, formerly described by Colonel Helmersen† (see p. 374). Occurring at Tolks and Pungern, this shale is very rich in well-preserved fossils, including many trilobites of the genera Ampyx and Trinucleus, as well as the long-known typical British shell, Leptæna sericea of Sowerby.

Then follows a fine-grained limestone, which, forming the northern half of the Isle of Dagden, is, according to Professor Schmidt, who has worked out the details of this region, the upper limit of the Lower Silurian rocks of Russia. The fossils contained in this band are indeed

* In citing the name of Eichwald, I must express my regret, that, after demonstrating the identity of the strata forming the sea-board of the Baltic provinces of Russia with the rocks of Britain under the term Silurian (Silurische System in Esthland, 1840), he should, in a recent memoir, have gone back to the obsolete term "*Grauwacke*." The use of this word, as respects the Russian Baltic rocks of this date, is wholly inapplicable; since no one band of these presents the lithological character of "Grauwacke." (See 'Der Grauwackenschichten von Liev- und Esthland,' Bull. de la Soc. Imp. de Moscou, 1854, p. 3.) See also his latest memoir (Bull. de Moscou, 1856–57) for copious lists of all the known paleozoic fossils of Russia; the distinctions of Lower and Upper Silurian, Devonian, &c., being omitted, and "*grauwacke*" again brought into fashion.

† In addition to various able memoirs which he has written on the crystalline and paleozoic rocks of Russia, to the geological maps which he has prepared, and to his late works on the Devonian rocks, my associate in the Imperial Academy of St. Petersburg, Colonel Helmersen, has published an account of the nature and position of this schist. It is certainly one of the oldest deposits which have combustible properties, though the anthracitic layers of the South of Scotland seem to lie quite as low in the series. It is probable that most of the bituminous and anthracitic beds of these early periods owe their carbon and hydrogen to decomposed marine vegetables and the soft bodies of graptolites. (See Helmersen, 'Sur le Schiste argileux-bitumineux d'Esthonie,' Journal des Mines de Russie, 1838, p. 97.)

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all truly of the age of the Caradoc beds of Britain, including the Calymene brevicapitata, Portl., Encrinurus multisegmentatus, Portl., Leptæna sericea, Sil. Syst., Orthis Actoniæ, O. testudinaria, with Murchisonia bicincta, Hall, and various types known in rocks of this age in America. This limestone, which contains also several characteristic shells of the inferior "Pleta," including the Orthis Lynx and Chætetes Petropolitana, terminates upwards in beds laden with corals of the genera Halysites, Heliolites, Caninia, Sarcinula, &c.

Upper Silurian.—In our large work on Russia, Upper Silurian deposits, like those of Gothland, were only spoken of by myself and companions as existing in the Isles of Öesel and Dago, which we did not visit. With the little time at our command, and in a flat country much obscured by drift, we did not pretend to draw any defined line between the Lower and Upper Silurian. Seeing, indeed, that the Pentamerus oblongus occurred in a calcareous band ranging above the Lower Silurian cliffs of Esthonia, it was natural on my part to refer that stratum, as I had done in England, rather to the top of the lower than to the base of the upper group.

Subsequent researches, however, and the preponderance of certain Wenlock fossils, have rightly led the Russian geologists to class this Pentamerus band with the Upper Silurian*. In truth, the whole series in Russia, as in Scandinavia, is of such very small vertical dimensions—not, perhaps, a fortieth part of the magnitude of the grand British

* M. Ozersky, who translated the work by myself and associates—'Russia in Europe'—into the national language, was the first person to call attention to the succession of those upper calcareous Silurian strata; though, when he wrote, the fossil distinctions now worked out were unknown. Afterwards, in a short article (Ermann's Archiv für Russland, 1848, p. 236), M. Pander noticed the superposition of a rock charged with Pentamerus oblongus and many corals, to the well-known lower limestone of St. Petersburg. Another important contribution to clear up the subdivisions of the Russo-Baltic Silurians was given by Professor Kutorga, in a map of the Government of St. Petersburg, the result of ten years of labour (Compte rendu de la Société Minéralogique de St. Pétersbourg, 27 Janvier, 1852). Representing a continuous band of Upper Silurian between the Devonian and the Lower Silurian to the *west* of St. Petersburg (a tract which I never examined), he admits that, to the south and east of the metropolis, the succession is what my friends and myself represented it to be; viz. Devonian rocks at once resting on Lower Silurian, with one or two minute traces only of the lower band of the Upper Silurian, or the limestone with Pentamerus oblongus. Wherever, as in Russia and America, that fossil, or its representative form, *appears for the first time, in ascending order*, in strata otherwise charged with Wenlock fossils, the geologist has a perfect right to class the rock as Upper Silurian. Kutorga had previously shown that the Pentamerus zone of Esthonia is surmounted, in the islands of Öesel, Dago, and Möen, by still higher Silurian strata. These Russian isles seem, in fact, to be equivalents of the southern end of Gothland (Hoburg), where I have described certain strata which represent the Ludlow rocks (Quart. Journ. Geol. Soc. Lond. vol. iii. p. 1). In another work, 'Uebersicht des Silur-schichten Systems Liev-lands und Esthlands,' 1852, M. Schrenk, the well-known explorer of the botanical and mineral condition of the North Ural Mountains, has, in conjunction with Professor Schmidt, extended considerably the range of the Upper Silurian; but the work of the last-mentioned author is that which, in conjunction with the great paleontological labours of Pander, has recently thrown the clearest light on the subject.

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deposits—that in a region where all these strata are conformable, and where, to use the expression of my associate Keyserling, all the strata (about 1500 feet thick) are but *leaves in one united calcareous volume*, no distinctions can be drawn except by close examination of the organic remains.

The chief mineral masses of these overlying rocks are fine-grained limestones, passing in some beds almost into marble, and thus presenting a contrast to the incoherent and earthy Lower Silurian limestones of St. Petersburg; and magnesian beds (dolomite) occasionally somewhat crystalline and cavernous, here and there charged with white siliceous concretions. In other parts the strata are friable, marly, and of grey and yellow colours.

Rocks having the same mineral aspect, and containing the same fossils, appear, as I am informed by Keyserling, along the edge of the Timan Hills, in the distant region of the Petschora, at the mouth of the river Gatchina, and near the shore of the Icy Sea. It is further to be remarked, that neither there nor in Esthonia (*i. e.* in tracts 1000 miles distant from each other) has there been detected the slightest unconformity between the Lower and Upper Silurian rocks.

The task of working out the organic remains as respects Esthonia, and the adjacent Russian isles of Wörmes, Dago, Öesel, &c., has fortunately been accomplished since the first edition of this work was published, by Professor Schmidt of Dörpat, whose views, as communicated to me by my associate Keyserling, have been recently published*. The coralline limestone forming the summit of the Lower Silurian graduates in the same cliffs into a more marly limestone with Pentamerus linguiferus, Strophomena Pecten, and other fossils. The upper portion of the band is everywhere characterized by a profusion of the Pentamerus borealis, another species (probably the Pentamerus oblongus, Sil. Syst.) being partially distributed; whilst the associated fossils are Calymene Blumenbachii, Encrinurus punctatus, Leptæna depressa, Atrypa reticularis, Leperditia Baltica and L. marginata, with many corals. Next follows a bluish-grey marlstone, in part a hard subcrystalline dolomite, whose chief fossils would seem to refer the rock to the Wenlock age, such as Lichas Gothlandicus, Orthoceras annulatum, Sil. Syst., Orthis elegantula, Dalm., Leptæna transversalis, &c. This zone also contains many other Upper Silurian species.

The uppermost Silurian rock (as developed in the isles of Öesel, Dago, and Möen) is a crystalline limestone, rarely dolomitic, the beds of which alternate with marly shale. This deposit contains Ludlow rock mollusca, such as Pterinea reticulata, Grammysia cingulata, Orthoceras bullatum, Sow., Murchisonia cingulata, Trochus helicites, Rhynchonella Wilsoni, Orthis orbicularis, and the Eurypterus remipes; the last-men-

* Quart. Journ. Geol. Soc. vol. xiv. p. 43.

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tioned being a representative of the group of crustaceans which so abound in the Ludlow rocks. Again, the resemblance of the Russian to the British deposit is marked by ichthyolites, many genera and species of which are described by Pander in his new work.

One of the finest of these uppermost Silurian species is the Cephalaspis verrucosus, Pander (Thyestes, Eichw.), a genus which in England first appears in this zone, whilst with it, in the Isle of Öesel, as also near Ludlow, is found the Onchus Murchisoni (see p. 256 *et seq.*, and Pl. 35. f. 13, 14)*.

These grey beds, so manifestly identical, through many of the species of their invertebrated organic remains, with those of the Upper Ludlow rocks, present, however, no transition, as in England, into the superjacent red or Devonian strata. The lowest zone of the Old Red, characterized by its Cephalaspis Lyellii, Pteraspides, and Pterygoti, does not exist in Russia, where a hiatus occurs, the Middle and Upper Devonian being transgressive to various Silurian rocks in the Governments of Esthonia, Livonia, and St. Petersburg.

Devonian Rocks of Russia.—Deposits of this age are so very widely spread out in Russia, as to extend over a region more spacious than the British Isles. This great extension is not, however, due to the thickness, but to the very slight inclination of the beds, and to their having been rarely disturbed. Though subjected to broad and very slight bends only, they occupy the chief part of the Valdai Hills, and rise into a broad dome near Orel; thus constituting the highest eminences of a comparatively low region.

In addition to many shells, some of them peculiar to the region, but others well known in strata of the same age in the limestones of Devonshire, in the Eifel, and some portions of the Devonian rocks of the Rhine and the Boulonnais, fossil fishes occur in numerous localities, and strikingly characterize this deposit in Russia. Many of them, brought to England by myself, were shown by Agassiz to be identical with species of the Scottish Old Red Sandstone; whilst, from a microscopic examination of their teeth, Owen proved that some belong to Dendrodus†, a genus of sauroid fishes equally characteristic of the North British formation. The Cephalaspis Lyellii and the Pteraspides, which, with their associated large crustaceans, the Pterygoti, characterize the lowest zone of Old Red Sandstone in England and Scotland, are, as before said,

* In addition to the Cephalaspides (of several species), Prof. Pander describes the following genera of Upper Silurian fish, mostly Ganoids, viz.: Rytidolepis, Schidiosteus, Coccopeltus, Cyphomalepis, Trachylepis, Stigmalepis, Dasylepis, Lopholepis, Dictyolepis, Oniscolepis, Phlebolepis, Melittomalepis, Tolylepis, Lophosteus, Pterichthys, Cœlolepis, Pachylepis, Nostolepis.—The Ichthyodorulites are: Rhabdacanthus, Prionacanthus, Onchus.—The teeth are named — Aulacodus (Sphagodus, Eichwald), Strosiphorus, Odontodus, Gomphodus, Coscinodus, Monopleurodus. If, by further comparison, several of these genera should disappear, the researches of M. Pander will still have made a very considerable addition to Upper Silurian ichthyology.

† 'Russia in Europe,' &c., vol.i. p. 635.

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unknown in Russia,—a zoological datum which is in perfect harmony with the physical break observed, whereby this band is omitted, and the fishes of the middle and upper portion of the Old Red series of Scotland lie in strata which repose *transgressively* on various members of the Silurian rocks.

When the first edition of this work was published, the existence of the Coccosteus, so characteristic of the central zone in the north of Scotland, was unknown in Russia. But now, thanks to the labours of Pander, the comparison is rendered still more striking, not only by the addition of that remarkable form, but also of other well-known genera of the Caithness flags—Osteolepis, Diplopterus, and Dipterus. The other Scottish forms, and even species, found by myself and companions, were, indeed, long ago identified by Agassiz and Owen as having their exact representatives in Russia. Such are the great Asterolepis (Chelonichthys) Asmusii, Ag., and the smaller species, A. minor, Ag., Glyptosteus favosus, Ag., Bothriolepis ornata, Eichw. (Glyptosteus reticulatus, Ag.), Holoptychius nobilissimus, Ag., Dendrodus strigatus, Owen, D. biporcatus, Owen, Cricodus incurvus, Ag. (Dendrodus, Owen), Pterichthys major, Ag., &c.* ; all belonging, as already shown (p. 286), to the central portion of the deposit in Scotland†.

When my colleagues and myself explored Russia, the connexion between the character of the fossils and the nature of the matrix in which they are imbedded was more pointedly brought before us in our range over that vast Empire, than in any other region with which we were acquainted. In Courland, Livonia, and the Baltic Governments, as well as in the great central dome-like region of Orel, to which the formation extends, and where it has since been examined and ably described by Helmersen, finely laminated limestones alternate with, and are subordinate to, great masses of sand, marl, and flagstone; and whilst in the

* 'Russia in Europe,' &c., vol. i. p. 40, and fig. p. 636.

† The last work of Pander—and other fasciculi are announced (Ueber die Placodermen der Devonischen System)—is a singularly valuable contribution to Palichthyology. The author adopts M'Coy's term of 'Placoderms' to denote a family composed of the genera Asterolepis, Eichwald, Coccosteus, Ag., Homosteus and Heterosteus of Asmus, and Chelyophorus, Ag. The Asterolepis, however, is not the Asterolepis of Hugh Miller. For the latter, Asmus's name Homosteus has the priority; while the Pterichthys of Agassiz is that which was first termed Asterolepis by Eichwald.

M. Pander has evidently studied a great number of specimens of Asterolepis (Pterichthys) and Coccosteus with extreme care. He gives restorations of each, and figures of all their separate parts, which will be of very great value to the paleontologist; while his laborious attempt to unravel the complexities of the synonymy of these fishes is worthy of all praise.

The following genera have, according to him, been based wholly or partly on different portions of—1st. Asterolepis alone!—Bothriolepis, Ag., Chelonichthys, Ag., Glyptosteus, Ag., Pterichthys, Ag., Pamphractus, Ag., Homothorax, Ag., Placothorax, Ag., Odontacanthus, Ag., Ctenoptychius, Ag., Narcodes, Ag., Cosmacanthus, Ag., Placosteus, Ag., Psammolepis, Ag., Ctenacanthus, Ag., Cheirolepis, Eichwald, Microlepis, E., Chelyophorus, Ag. The other genera are—2nd. Coccosteus, Ag.; 3rd. Homosteus, Asmus (Asterolepis, Ag.); 4th. Heterosteus, Asmus (Asterolepis, Ag., Ichthyosauroides, Kutorga); 5th. Chelyophorus, Ag.

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calcareous courses mollusks prevail, mixed with remains of fishes, the latter are found most generally in sandy and marly beds. In tracing these rocks from the Baltic provinces to the White Sea and Archangel, the limestones thin out, and the group is there represented only by sands and marls.

Accordingly we find, that where the rocks have the sandy character of the chief masses of Old Red Sandstone in the British Isles, there they are exclusively tenanted by fishes;—a remarkable proof of the accordance between the lithological character and organic contents of rocks of the same age in very distant countries.

Another and not less remarkable fact brought out by the survey of Russia is, that the same fossil fishes, of species well known in the middle and upper portions of the Old Red of Scotland, and which in large tracts of Russia lie alone in sandstone, are in many other places found intermixed, in the same bed, with those shells that characterize the group in its slaty and calcareous form in Devonshire, the Rhenish country, and the Boulonnais. This phenomenon, first brought to light in the work on Russia by myself and colleagues, demonstrates more than any other, the identity of deposits of this age, so different in lithological aspect, in Devonshire on the one hand, and central England and Scotland on the other. The fact of this intermixture completely puts an end to all dispute respecting the identification of the central and upper masses at least of the Old Red of Scotland with the calcareous deposits of Devonshire and the Eifel. As this circumstance had been slightingly spoken of by critics, I wrote to my colleague, Helmersen, to enable me to reassert the fact on his own knowledge, and he has assured me, that this intermixture is visible in numerous parts of Russia; and that any person who may be sceptical has only to visit the Museum of the Imperial School of Mines to witness frequent examples of typical Devonian mollusca in the same hand specimen with Old Red ichthyolites like those of Scotland*.

A similar intermixture has indeed been since recognized, to some extent, in the Devonian rocks of the Eifel and the Harz, and also in North America.

The progress of research had enabled M. Kutorga to divide the Devonian rocks of a part of Russia into three stages, in the ascending order of clay and marl with Lingula bicarinata, compact sandstone with many ichthyolites, and argillaceous limestone with many brachiopods.

* I can also cite with satisfaction another confirmation of my views, as conveyed in a letter I lately received from so high an authority as M. Pander, who thus writes:—"The Devonian rocks, which are so clearly described in your work, that one could almost find them in the dark, have attracted my particular attention on account of their fishes. *For, by these remains, together with the characteristic Brachiopoda and Acephala, the agreement of the rocks of this system in Russia and Britain is shown in the clearest way.*" —April 1858.

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M. Pander, in the notice previously referred to, has even shown that the highest of these beds is covered by other sandy strata, in which fossil fishes of the Devonian epoch equally abound.

This author also distinguishes three stages in the Devonian rocks of Russia. The lowest consists of sandstones and shale, with those ichthyolites which abound in the North of Livonia and the environs of Dörpat and Tellin. These are the fishes which M. Asmus made known, and which Pander has described in his first fasciculus as Devonian Placoderms. In these beds shells are rare; but the Lingula does occur, and its presence alone clearly shows, that the associated fishes were also inhabitants of the sea. These strata contain the same fishes as the Caithness and Elgin beds of the North of Scotland. The next stage, consisting of limestones, both dolomitic and simple, and of shales, is laden with *marine* mollusca, which are mixed up in the same beds with various ichthyolites, and extend over wide spaces. In this zone, as Colonel Helmersen informs me, the Productus productoides, Terebratula Livonica, Spirifer Archiaci, S. Anosoffi, and many other shells, with Corals and Encrinites, are often commingled with remains of Holoptychius nobilissimus, and numerous bones and plates of other fishes which Pander is describing. This is manifestly one of the stages of the Old Red Sandstone of Scotland, the Holoptychius and other fish-remains of which are thus proved to be of purely marine origin.

The third and highest stage, consisting of reddish sands, occasionally with green marls, and which seems to be simply an upward continuation of the band below it, contains also some of the same Holoptychius with other fish-remains.

In the more southern tracts near Voroneje*, it was shown, by myself and associates (and the phenomenon is now known to prevail in many other tracts), that many species of marine brachiopods were absolutely commingled with fishes in one and the same marly stratum. It follows therefore, that the minute distinctions, lithological and organic, traceable in one district are not applicable to another; and that the limestones are mere mineral accidents in a great arenaceous and marly series of strata; whilst, on the whole, the identification of the group with its equivalents in other parts of the world has been established in the clearest manner by means of the fossil contents.

Reposing, as a whole, on the uppermost Silurian in Esthonia, and on Lower Silurian in the Government of St. Petersburg, the upper members of these Devonian strata are in numberless places overlaid conformably by and pass up into carboniferous limestone. In some tracts the strata consist of flag-like, shelly limestones and marls, in others of sandstones both soft and hard, which range over extensive northern districts to the banks of the Lake of Onega and the shores of the White Sea.

* 'Russia in Europe,' &c., p. 60.

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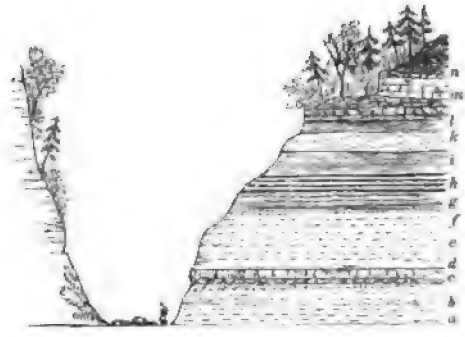
In certain parts, as in the Valdai Hills, the upper beds, represented in the following woodcut, are red and green marls, containing several of the above-named fossil fishes of the Old Red Sandstone of Scotland; the whole mass being covered by carboniferous limestone with its usual fossils, including many Producti.

RAVINE OF THE BELAIA IN THE VALDAI HILLS.
(From 'Russia in Europe,' p. 46.)



The lower beds, *a*, *b*, *c*, *d*, *e*, *f*, consist of various sands and marls, in which ichthyolites are disseminated; but the bed *d* is a complete congeries of fish-bones, surmounted by a copious mass of red, white, and green marls. Then follow bituminous schists, *g*, *h*, *i*, with courses of bad coal, constituting the bottom beds of the carboniferous deposits; and, after other alternations of sands and marls, *k*, *l*, they are followed by the carboniferous limestone, *m*, *n*, with many characteristic fossils, including even species which are well known in Britain, such as the Productus hemisphæricus, P. punctatus, and P. semireticulatus.

In the distant region of the Petschora, Count Keyserling obtained satisfactory evidence, that certain beds charged with Goniatites are inferior to all the other Devonian strata of Russia, whilst, as we shall presently see, the chief goniatite deposit on the banks of the Rhine is underlaid by fossiliferous limestone and sandstones of great thickness, which there constitute the central and lower members of the Devonian series.

It seems, indeed, certain that there is no known equivalent in Russia of the Système Rhénan of Dumont, or great "Spirifer-Sandstein," which forms the fossiliferous base of the Devonian rocks of the Rhine*. This inference is indeed sustained by the fact already adverted to (p. 380), that the Upper Silurian of Russia is nowhere surmounted by that band charged with Cephalaspis and Pteraspis, which constitutes the lowest member of the Old Red Sandstone of Britain, and which I consider to be the exact equivalent of the Spirifer-Sandstein of the Rhine. That the Devonian rocks of Russia are completely independent of the Silurian, is therefore demonstrated both by their peculiar fauna, and by their reposing in one tract on Upper, in another on Lower Silurian rocks, as demonstrated by Helmersen†, Kutorga, Schmidt, and others.

Carboniferous Rocks of Russia.—Of the Carboniferous group, as exhibited in Russia in Europe, it is enough to say, that its lowest

* According to M. Barrande, Goniatites occur in the Upper Silurian of Bohemia.

† In addition to Colonel Helmersen's survey of the Devonian rocks, which extend so largely throughout Central Russia, M. Raimund Pacht has also described, in some detail, the nature of these rocks, and a portion of their fossils, as they occur in Livonia (Devonische Kalk in Lievland. Dörpat, 1849).

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members only are there well developed. In the small section above given (p. 384), we see beds of carboniferous limestone, with traces of coal, lying immediately on the red and green rocks with Devonian fishes. To the north-east, or on the Andoma River in the Government of Olonetz, the calcareous members of this division swell out; but even the few thin seams of poor coal above mentioned disappear, and are represented by one course of black and very slightly bituminous shale.

Near Moscow, efforts have recently been made to reach coal by boring through the superjacent Jurassic rocks (Oxfordian), which there cover the carboniferous limestone; but, according to Helmersen, no coal was detected at a depth of 490 feet. Ranging from Moscow by Serpuchof to Tula and Kaluga, where the carboniferous limestone again comes out to the surface, two seams of poor coal have been partially worked at Serpuchof; but they are of very slight value only*. In the southern region of the Donetz, between the Don and the Dnieper, where these lower strata reappear, the coal-seams are indeed of much larger dimensions, and several of them are of much better quality. They are there all interstratified with beds of carboniferous limestone, like the Scotch coal-fields (p. 312).

In the last tract, however, the horizontality of the paleozoic strata in the northern parts of this vast country, which would have rendered the coal-beds valuable, no longer exists. The limestone, sandstone, and shale, with coal, have here been violently extruded to the surface through a cover of surrounding Jurassic and even cretaceous deposits, and, being very highly dislocated, are consequently difficult to work.

But if Russia should open out deep shafts *around* the field of the Donetz†, the good beds of coal which she possesses in the south may be found to lie in valuable and regular masses beneath the unbroken and surrounding secondary rocks.

Some of the grandest examples of the carboniferous limestones of Russia are to be seen on the banks of the Volga, near Syzran, the bend which that mighty river makes, as delineated on all maps, being caused by lofty cliffs of those rocks which frown over the low region on the east. There, thick beds, containing numerous fossil species common to this division in many quarters of the globe, are laden with the small

* Helmersen, 'Ueber die Bohrarbeiten auf Steinkohle bei Moskau und Serpuchow;' Mélanges Phys. et Chim. Petersburg, 1856.

† In the work on Russia I suggested, that, if the Imperial Government should make trials for *what may very probably prove to be a valuable and unbroken coal-field*, sinkings should be made on the left bank of the Donetz, through some of those surrounding horizontal secondary formations, not distant from the edge of the above-mentioned upcast and dislocated coal-field. (See 'Russia in Europe,' &c., p. 118 *et seq.*) I last year called the attention of the Emperor Alexander to this important subject, when I had the honour of an interview with his Imperial Majesty at Darmstadt.—April 1858.

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Fusulinæ, first noticed by Pallas, which are remarkable in being among the oldest of this group of foraminifers; the Fusulina being in truth the prototype of the Nummulite, which became abundant so long afterwards in the lowest tertiary deposits.

Other and not less gorgeous masses of the same limestone, but equally without coal, are displayed on the western flanks of the Ural Mountains, where they are united conformably in numerous undulations with underlying limestones containing Devonian fossils.

Not repeating sketches which are given in another work, I would refer the reader to this woodcut, in which masses both of Devonian and

DEVONIAN AND CARBONIFEROUS ROCKS IN THE GORGE OF THE TCHUSSOVAYA RIVER (WEST FLANK OF THE URAL MOUNTAINS).

(From 'Russia in Europe and the Ural Mountains,' vol. i. p. 386.)

Carboniferous limestone are seen in intimate connexion, but much dislocated at this spot, in the gorge of the river Tchussovaya on the western edge of the Ural Mountains. The clearest proofs are thus exhibited (the two formations being quite conformable), that the portion of the series, which is very slightly coal-bearing in central Russia,

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and much more so on the Donetz, is entirely wanting on the flanks of the Ural.

These carboniferous limestones, everywhere more or less characterized by their Producti, are overlaid along the western edge of the Ural chain by sandstones and grits, which occupy much the same place in the general series as the millstone grit of England. In that region, thin seams of coal have been worked on the banks of small affluents of the Tchussovaya, near Ust Coiva, and other places, in this representative of the millstone grit (see 'Russia in Europe,' vol. i. p. 126).

In Russia these strata are often, however, more calcareous, and contain goniatites. They constitute the uppermost courses of the Carboniferous group, properly so called, in the vast territory between the Volga and the Ural Mountains, where they are seen in many localities to be at once succeeded by the Permian deposits before described. These, the highest carboniferous beds, contain only at intervals very rare and thin traces of coal, and the great upper coal-fields of England have no representative in the Russian Empire.

In stating, however, that identical formations have a very dissimilar aspect, both mineralogically or physically, in tracts distant from each other, we have only to point to different parts of the vast Russian Empire itself. Thus, whilst the soft Lower Silurian clays and sands of St. Petersburg have their equivalents in the hard schists and quartz rocks with gold veins in the heart of the Ural Mountains, the equally soft red and green Devonian marls of the Valdai Hills are represented on the western flank of that chain by hard, contorted, and fractured limestones, as in the preceding sketch, made in the gorge of the river Tchussovaya.

The deposits of Silurian, Devonian, and Carboniferous age, which have remained spread out in wide, horizontal, and slightly broken masses over Russia in Europe, have, we thus learn, been so thrown up in the Ural Mountains as to constitute the metamorphosed and highly mineralized rocks, some idea of which is afforded in the preceding sketch. Other views given in a subsequent chapter on the auriferous rocks, will realize to the eye the condition of the more central and completely altered rocks of that chain. In the mean time it may be stated, that hard and crystalline, paleozoic, slaty strata, associated with numerous eruptive porphyries and greenstones, form the nuclei of all the mountainous ridges in Siberia, whether in the lofty Altai on the south-east, where some of them have been well described by M. Pierre de Tchihatcheff*, or in

* See the magnificent work, 'L'Altai Orientale,' of M. Pierre de Tchihatcheff. Some Devonian fossils have been found near Lake Baikal.

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those hills which act as separating barriers between the great rivers Ob, Jenissei, and Lena, and extend to the Sea of Ochotsk and Behring's Straits on the north-east. Recently, indeed, these phenomena have been traced over vast regions of Mongolia, the Kirghis Steppes, and the borders of Chinese Tartary and Central Asia, by that enterprising explorer and skilful artist, Mr. T. W. Atkinson, who leads us to believe that, in addition to the numerous eruptive rocks of ancient geological date, sub-aërial volcanos must have existed in parts of this extraordinary, and hitherto untrodden, wild, rocky region*.

Grand, therefore, as is the spread of soft and slightly coherent primeval rocks throughout Russia in Europe, the hard stony tracts of this age which extend over the Asiatic regions of the same great Empire are much more extensive.

Restricting our view to Russia in Europe, we see the Silurian and Devonian rocks rise partially to the surface in the southern provinces of Podolia, on the banks of the Dnieper; and, although no rocks of such high antiquity have yet been detected in the Caucasian mountains, they reoccur in the same latitude near Constantinople†, have been recognized in several parts of Asia Minor to the south of the Black Sea‡, and are also traced (most of their fossils belonging to the Devonian type) even to the southern flanks of Mount Ararat, and thence eastwards into Persia §.

* See Atkinson's 'Oriental and Western Siberia,' 1858.

† Proc. Geol. Soc. Lond. vol. ii. p. 437. The Turkish fossils are of the oldest Devonian age, and represent the Spirifer schist and sandstone of the Rhine, which, as well as their equivalent, the Lower Scottish Old Red Sandstone, are wanting in Russia.

‡ Tchihatcheff, Bull. Soc. Géol. Fr. vol. vii. p. 389. My enterprising friend Pierre de Tchihatcheff is now about to explore (as he writes to me) for the ninth time Asia Minor, visiting tracts which are blanks on Kiepert's Map, and particularly the countries of Turkish Armenia.—April 1858.

§ Abich, Quart. Journ. Geol. Soc. Lond. 1846, vol. ii. 2nd pt. p. 96; and 'Russia and the Ural Mountains,' vol. i. p. 652. Prof. Abich also found carboniferous limestones everywhere overlying these Devonian rocks, and characterized, too, by a small Fusulina, of a species distinct from that found in Russia. The memoir he has recently published, and particularly a large work, which, I rejoice to think, he is now preparing, under the auspices of the Russian Government, must throw great light on the physical structure of the whole chain of the Caucasus. In a memoir just received, M. Abich has offered several critical remarks on the Map of Europe completed by the able and ingenious M. Dumont shortly before his death, showing several errata of considerable magnitude in relation to the Caucasian region, most of which pertain to rocks of Secondary and Tertiary age, not treated of in this work. He states, moreover, that the violet colour which represents the Lower Devonian (Rhénan of Dumont) must be struck out as regards the tract lying between 38° and 47° E. long.; all that country being occupied by very old rocks and crystalline slates. In truth, however, the Map of Dumont, one half of which is taken from the Map of Russia in Europe and the Ural Mountains by myself and associates, must not be judged

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Looking, therefore, to the ancient crystalline rocks of Scandinavia, the origin of which is buried in obscurity, we know that they have been overlapped successively by those Silurian, Devonian, Carboniferous, and Permian strata which occupy such an enormous region in Russia. The discovery in Spitzbergen of certain Permian fossils, which have been clearly identified by de Koninck*, at once shows how widely spread were all these primeval deposits, and how they must have been successively accumulated around a large nucleus of pre-existing crystalline rocks.

by such ultra-European inaccuracies; for, although the classification of the stratified rocks of my late distinguished friend differs from that which I adopt, I much admire the clearness and beauty of his great work. For my own Geological Map of Europe (Johnston), as published with the assistance of Prof. Nicol, I claim more indulgence from my friends, as it was hastily issued, and contains errors of detail which I intend to correct. In extending his observations to the eastward, M. Hommaire de Hell discovered Devonian rocks in Persia, where they form the axis of the Elburz chain and the southern slopes of the mountains of Tchihennene, and are highly fossiliferous in the valley of Touva. (Bull. Soc. Géol. Fr. vol. vii. p. 500.)

* Bull. de l'Acad. Roy. de Belgique, vols. xiii., xvi.

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CHAPTER XV.

PRIMEVAL SUCCESSION IN GERMANY.

GENERAL SKETCH OF THE CHARACTER OF THE OLDER ROCKS EXTENDING WESTWARDS FROM POLAND AND TURKEY IN EUROPE INTO THE ALPS AND CARPATHIANS.—DEVONIAN, CARBONIFEROUS, AND PERMIAN ROCKS OF SILESIA AND MORAVIA.—SILURIAN ROCKS (LOWER AND UPPER) OF BOHEMIA.—LOWER SILURIAN, DEVONIAN, AND CARBONIFEROUS ROCKS OF SAXONY, THE THÜRINGERWALD, ETC.

IF the general order of the older strata be so clearly exposed in the vast portion of Russia in Europe which has, from the remotest antiquity, been exempted from all intrusion of every description of plutonic or volcanic rocks, we no sooner pass to the south-west and enter the Danubian and Turkish provinces, than we meet with masses more or less crystalline, which, like those of the Ural Mountains and Siberia, have been penetrated at various localities by igneous matter. These extend from the Balkan into the ranges of Thrace and Transylvania on the one hand, and into the Carpathians on the other, but have as yet been so little examined in detail, as to leave us in ignorance of the extent to which a paleozoic classification can be applied to them. From the travels of Boué, Warington Smyth, and others, it is, however, known, that these rocks are usually so crystalline, as to afford few spots like those near Constantinople, just alluded to, where the paleontologist can expect to observe even a few rare fossils.

When, however, we reach the Eastern or Austrian Alps, we find that, although most of the strata comprising the mighty pile of these mountains have been metamorphosed, there are certain "oases" at wide intervals, indicative of a succession similar to that which we have been following through other countries. Thus, in the ridge south of Werfen in the Salzburg tract, Orthoceratites, Orthidæ, Cardiolæ, and other fossils have been detected, marking a remnant of a true Silurian zone, the chief mass of which is in a crystalline state. In the Styrian Alps near Gratz, certain grey schists and calcareous flagstones contain a good many Devonian fossils, and

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similar rocks have there been traced through a district of some extent.

Near Bleiberg, in the Carinthian portion of the Eastern Alps, is a limestone with large Producti, which is universally recognized to be of carboniferous age; whilst in various parts of the Western Alps, the rocks contain courses of anthracite, associated with plants of the same era. On the whole, however, it may be said, that in nearly all the countries extending over the southern regions of Germany, the clear separation of the paleozoic rocks, which can be easily effected in many other parts of Europe, is impracticable. This is doubtless owing, in great measure, to numerous mutations of structure, as well as to the dislocations and inversions which all the rocks have there undergone, from the Silurian to the Eocene Tertiary inclusive.

When, however, we travel westward in a more northern parallel, and pass from the central provinces of Russia into Poland, Prussia, and the northern states of Austria, we find, that, although the paleozoic rocks of those regions have no longer the wholly unaltered facies which they presented to us on the banks of the Neva, the Volga, and the Dwina, and though they have, unlike their Russian equivalents, been penetrated by many eruptive rocks, yet they contain numerous examples wherein order and the normal relations may be clearly observed.

In Poland, and in many low districts of Northern Germany, so widely spread are the younger secondary and tertiary deposits, that the rocks under consideration rise only in small patches to the surface. Thus, around Kielce*, to the south of Warsaw, a nucleus of Devonian rocks, with much limestone, and charged with many characteristic fossils, is followed by carboniferous limestone and thick-bedded coal-seams, over a small district that ranges from Russian Poland into the Silesian coal tracts of Prussia. Thence to the westward, rocks which have been, or may be classified as Silurian, Devonian, Carboniferous, and Permian occupy detached districts in Prussia, Saxony, the smaller states of Germany, large tracts in the northern territories of Austria (particularly in Bohemia), and also in parts of Moravia.

In traversing the Riesen-gebirge to the south of Breslau, the geologist acquainted with the full development of the paleozoic rocks of other regions is struck with the comparative tenuity of the Devonian and Carboniferous deposits. In large portions of these mountains (the mineral characters of which have been recently examined in detail by M. Gustav Rose, whilst their geological distinctions will soon be laid down on a map by M. Beyrich), the strata of Silurian age have, for the most part, undergone a complete metamorphosis. They have indeed passed so generally into crystalline schist and marble, that the rarest

* See 'Russia in Europe,' vol. i. p. 39.

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fossils only of the earlier era have rewarded the labours of the eminent men above mentioned, or of my old friends Dechen and Oeynhausen, who first explored their range. That these older crystalline strata are, however, the equivalents of the Silurian rocks is certain, because they have recently been found to contain *Graptolites*, and are further clearly surmounted by limestone, charged with many Devonian forms. In the district of Waldenburg, south of Breslau, and at Silberberg, to the north of Glatz, the Devonian limestone, having a thickness of 50 to 60 feet only, is charged with Clymeniæ and many other typical fossils. It is covered by an overlying limestone, of no greater vertical dimensions, laden with great Producti and several other shells well known in the mountain limestone of Britain*, especially those of the lower carboniferous zone; the two beds being separated by thin strata of schist. This carboniferous limestone is overlaid by rocks occupying the place of the millstone grit of English geologists, and which, assuming very much the same mineral characters as the rocks whereon they repose (being also perfectly conformable with them), were in old times confounded with the so-called and undefined "grauwacke." It is in this portion of the series, *i. e.* in the schists and sandstones associated with the carboniferous limestone, that several of those plants have been found, which Professor Göppert has described as of transition age (Calamites transitionis, &c.). Above these schists and sandstones come the small productive coal-fields of Waldenburg, succeeded by a copious development of red rocks (Roth-liegende), grouped many years ago with those Permian deposits, and which have already been described (p. 343)†.

Again, in Moravia, from all that I can learn, whether from examining the collections of Professor Glocker of Breslau, who has so long explored that province, or from consulting a work of Professor von Hingenau‡, or from a partial, personal survey in 1847, it would appear that the order of the older paleozoic deposits is very analogous to that which prevails in Silesia. There I have observed crystalline schists and limestone, representing Silurian formations, followed by masses of limestone, which at Rittberg and other places around Olmütz are charged with Devonian fossils. Some of the strata, in tracts that I have not seen, are referred to the Carboniferous era. The crystalline rocks which range thence, or from the Sudeten Mountains into the Böhmerwald-gebirge, and have been generally described by Partsch§, Heinrichs, and others, consist of gneiss, mica-schist, chlorite-schist, and hornblendic slates, with saccha-

* At one spot, Falkenberg, I collected in the carboniferous limestone the following fossils, viz. Productus gigas, P. semireticulatus, Strophomena analoga, S. crenistria (var.), Spirifer lineatus, S. pinguis, S. glaber, with a minute Phillipsia, a small Orthoceras, and several species of corals.

† See 'Russia in Europe and the Ural Mountains,' vol. i. p. 200. I examined this tract alone, in the year 1844.

‡ 'Uebersicht der Geologischen von Mähren und Oesterr. Schlesien.' Wien, 1852 (with a Map).

§ Jarhb. K. K. Geol. Reich. 3. Heft, 1851.

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roid limestones; the whole being penetrated by granite, syenite, greenstone, serpentine, &c. Although portions of these vast masses must represent, in my belief, the Silurian series, the greater part of the schistose rocks, including limestones, in which fossils have been detected, are clearly of Devonian age, as has been elsewhere shown*.

Silurian Rocks of Bohemia.—If the traveller has worked his way round from Britain through Scandinavia and Russia into North-eastern Germany, and has there lost the clue whereby he could have identified the lower crystalline schists and limestones of Silesia and Moravia with their representatives in the western, northern, and eastern regions of Europe, he will, indeed, be rejoiced when he enters upon the territory around Prague, and there sees, under the guidance of M. Barrande, a most complete and symmetrical exposure of the whole Silurian system, whether as respects the clear order of the strata, or a vast abundance of organic remains.

The geologist who would form an adequate idea of the relations of this "Bassin Silurien," so admirably developed by that author, must traverse the tract as I have done, from Przibram and Ginetz on the south-east, to Skrey on the north-west, or visit the environs of Beraun. He will then at once recognize the truthfulness and accuracy of the divisions, which have been established after a most indefatigable and persevering study of the rocks and their organic remains during the last twenty-four years. The simple and regular form of this basin, and the order in which its concentric deposits are arranged, have enabled its first true explorer to ascertain the existence of three characteristic faunas, containing eight local stages, into which Barrande divides what he has there called the "Silurian System." (See the annexed diagram†.)

* See Edinb. Phil. Mag. 1847, p. 66, and 'Devonische Formation in Mähren,' Leonh. N. Jahrb. i., 1841. The observations were made conjointly with my old colleagues, von Keyserling and de Verneuil, in the year 1847.

† Though the conclusions are stated briefly in the text, I must be allowed to say that they could have been arrived at only through intense labour and unwearied research, as well as by the liberal employment of Bohemian workmen. The last twenty years have been occupied in unravelling this grand and rich Silurian fauna. To most persons the acquisition of the Bohemian or 'Czeck' language would have been an insurmountable barrier; but, finding that without this key he could not direct his workmen, M. Barrande mastered the difficulty, and made himself a Bohemian scholar in order to become a thorough geological expounder of these rocks. His Silurian collections are certainly more interesting than those ever made before by any one individual; and the evidences of faithful scrutiny and of a philosophical spirit pervade all the pages of his great work, which must, I am sure, be duly appreciated by every geologist and naturalist who consults it.

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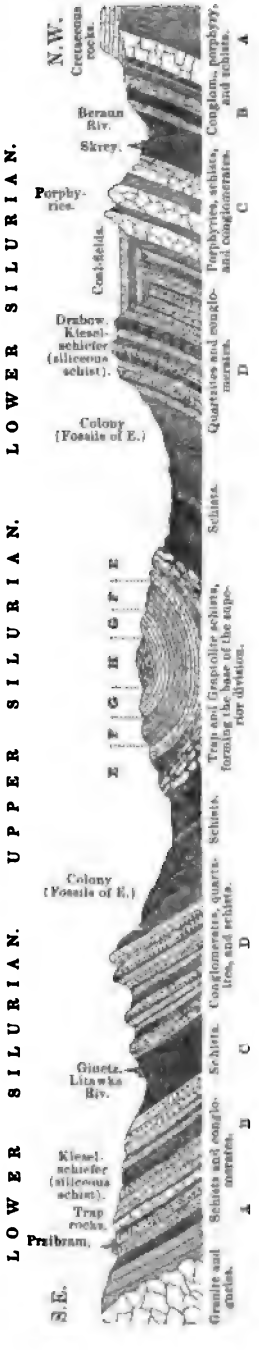
GENERALIZED SECTION ACROSS THE SILURIAN BASIN OF CENTRAL BOHEMIA, BY M. JOACHIM BARRANDE.
(From Barrande's Système Silurien de la Bohème, vol. i. p. 56 b.—See also Bull. Soc. Géol. France, 2 sér., vol. viii.; and Leonhard's N. Jahrb. 1847, tab. i.)



Just as in the British Isles, the lowest fossil-bearing strata, C of the section, repose on a vast mass of azoic schists, conglomerates, and grits, A, B. These are in parts semi-crystalline, and rest upon gneiss* and granitic rocks. The argillaceous schists, C, the lowest in which fossils occur, he terms "Faune Primordiale." This primordial fauna is specially characterized by trilobites of the genera Paradoxides, Conocephalus, Ellipsocephalus, Sao, and Agnostus; and it also contains a rare Orthis and some Cystideæ, and some species of Pteropods belonging to the genus Theca. According to the opinion of M. Barrande, in which I entirely agree, this zone is represented (as before said, p. 43) by the rocks containing Lingula, Agnostus, Conocephalus, and Paradoxides in North Wales, and also by those which in the south-west flank of the Malvern Hills contain the Olenus; whilst, as has already been noted, Olenus, together with Paradoxides and Agnostus, are typical of the lowest band containing animal life in Scandinavia (the Alum slates, 2, of the section, p. 368, or Regiones A, B, of Angelin). The large species of Paradoxides in Bohemia also belong to the same primordial group. And to the same epoch must be referred the curious forms which have recently been described by Dr. Dale Owen as characterizing the lowest Silurian rocks of vast tracts in North America.

The next zone or stage, D, formed of schists and quartzose sandstones (quartzites), represents the great su-

* The crystalline rocks have recently been explored by Hochstetter and other Austrian geologists, whose observations completely confirm the conclusions of M. Barrande. (See Jahrbuch K. K. Geol. Rcich.)

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perior mass of the Lower Silurian, and is charged with abundant casts of Trinucleus, Ogygia, Asaphus, Illænus, Remopleurides, and many other trilobites. In it also has been observed the same relative development of the genus Orthis among the brachiopods, and of Cystideæ among the echinoderms, which stamps the character of the Lower Silurian rocks of Scandinavia, Russia, Britain, and North America.

Prague, with its Imperial palace, the Hradschin, stands upon these Lower Silurian rocks, which, dipping under Upper Silurian schists and limestones to the south of the city, rise up again to the surface on the banks of the Moldau, a few miles further south, and thus exhibit the superior members enclosed within a trough.

M. Barrande places the base of his Upper Silurian, or bottom of his stage E, where the quartzites with Trinuclei (Caradoc sandstones), &c. are overlaid by black schists containing many graptolites. Several bands of greenstone and trap, which the author considers to be of contemporaneous age, are interpolated in this portion of the series, and the shales are followed by grey, argillaceous limestone replete with a very rich fauna, unquestionably of an Upper Silurian type. But, although it might be contended, that, as in other countries, the schists which contain both the double and simply serrated graptolitic bodies ought rather to be classed with the lower division, no one can doubt that the limestones into which those schists graduate upwards, represent the true Upper Silurian type, so well marked in England and Gothland. Thus, in these we meet with the well-known fossils Cardiola interrupta, C. fibrosa, Phragmoceras ventricosum, P. arcuatum (Cyrtoceras, Barr.), Orthoceras annulatum, O. nummularium, Rhynchonella (Terebratula) navicula, R. obovata, R. Wilsoni, R. marginalis, Nerita Haliotis, Pentamerus Knightii, P. galeatus, Spirifer trapezoidalis, and forms of Leptæna, all of them published in my original work as Upper Silurian *species*. Again, most of the zoophytes which so characterize the Wenlock and Gothland limestone are here found in profusion, including the widely known corals, Halysites (Catenipora) catenularius, Favosites Gothlandicus, &c. Even that fossil, which has not otherwise, I believe, been detected out of England, the Ischadites Kœnigii, Sil. Syst., has been here collected in great quantities. It is also in this rich stage (E) that the Cephalopods have their maximum development, as represented by 400 species in this band only, there being among them many species of the true Nautilus. The Crustacea, Acephala, Gasteropoda, and Brachiopoda occur in about the same remarkable proportion; M. Barrande having described no less than seventy-eight species of Trilobites from this one limestone; the chief genera being Acidaspis, Calymene, Cheirurus, Cyphaspis, Lichas, Phacops, Harpes, Bronteus, Proetus, and Arethusina.

Ascending from this limestone (E of the section), the remaining and

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superior stages of calcareous rock (F and G) are so entirely conformable, are so often knit together in parallel folds in the same hill with the stage E, and are so connected zoologically as well as stratigraphically, that M. Barrande has united them all in one natural group, or his third fauna. The band F is a thin-bedded, hard limestone, occasionally containing huge concretions like the ballstones of the Wenlock limestone of England; it is usually of a light colour and somewhat crystalline, and therefore offers a strong contrast to the dark and earthy rock of the stage beneath it. This stage (F) is characterized by the first appearance of true Goniatites, which, as far as I know, have not been observed in so low an horizon in any other part of the world. Some of these are indeed larger than any previously known Goniatites. All intervening bands of shale and schist disappearing, the stratum F is at once surmounted by the highest limestone G, a rock usually of small concretionary structure, but which when laid open, as in large quarries on the banks of the Moldau (Branik, Wiskocilka, &c.), exhibits extensive, flattish masses with slightly undulating surfaces, the upper layers of which are covered by grey shale, H of the diagram. In these two uppermost stages nearly all the other classes of fossils expire, but many trilobites still prevail in them.

M. Barrande refers all these three limestones, including their shales, inferior and superior, to the Upper Silurian group, since he has found (just indeed as I long ago anticipated*) that the British division into Wenlock and Ludlow rocks was not to be looked for in distant lands. In truth, he has detected abundant Ludlow rock fossils in the lower limestone, E; and though the upper stages, F, G, H, contain some of the same species as that rock, they are also distinguished by many which are locally peculiar to each of them. In this way F is marked by its profusion of brachiopods, whilst the cephalopods, so abundant in the lower limestone, are reduced to a few. Of trilobites, though there are seventy-five species, they all belong to the same genera as those of stage E.

In G, or the highest limestone, there would seem, at first sight, to be some reason for classifying this mass rather as Devonian, seeing that, as well as the rock beneath, it contains Goniatites, a genus of cephalopods unknown in the Silurian of Britain, but abundant in the Devonian and carboniferous rocks of many countries. This one feature, however (and the Bohemian species are peculiar, and not known Devonian types), cannot prevail, in the opinion of the author, in the face of the much more decisive fact, that many true Silurian types pervade the three limestones, and unite them in one natural group. Thus, we here meet with forty species of trilobites of the genera before mentioned, with the addition of Dalmanites (Phacops). Now, although all these

* See 'Silurian System,' pp. 196, 301, *et passim*.

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genera, with the exception of Calymene, are known in the Devonian rocks, no one of the Bohemian species has been found in them*; and the resemblance is therefore confined to the brachiopod shells, of which a few species are certainly found in Devonian strata†.

Appended to his work‡ is an invaluable table (plate 51, vol. i.), containing the result of as much philosophical thought and profound research as were ever embodied in a single page of natural history; and in it M. Barrande brings proof at once before the eye, that every one of the few Devonian trilobites belongs to a genus which took its rise and had its maximum development in the Silurian period. In other words, they are only the expiring remnants of the crustaceans of the first great natural epoch in which those animals flourished. M. Barrande has also defined the upper limit of Silurian life by showing that his highest limestone contains three species of Calymene, a genus never yet found in the Devonian rocks; the form which was originally taken for a Calymene in the lowest Rhenish "grauwacke" being now recognized as a Phacops.

In short, more than 1800 species of fossils have already been obtained through the labours of this naturalist in working out the rich materials of his Silurian basin; and, as in Britain and other parts of the world, so in Bohemia, the most assiduous researches, aided by the microscope, have failed to detect the trace of a vertebrated animal below the uppermost Silurian rocks. In the two highest bands of these, and notably in the uppermost only, has M. Barrande obtained fragments of fish-bones. It is further remarkable that he has found the peculiar crustacean Pterygotus, ranging, as it does to a great extent in England, through the Upper Silurian rocks (p. 263 *et seq.*). See also Sil. Syst. pl. 4, and p. 606.

The geologist who may compare this edition with the last will have already perceived, p. 48 *et seq.*, that in the four years which have elapsed, many new or additional fossils have been detected in the lowest stages of the Llandeilo rocks, chiefly in the Silurian region of England and Wales, as well as in the crystalline quartz rocks and limestones of Sutherlandshire (pp. 196, 217).

Now, just in this interval of time has M. Barrande discovered, at the same horizon in his Silurian basin of Bohemia, a fauna which much resembles the same old British zone. Thus, the Æglina prisca, Barr., resembles very nearly the Æglina nodosa, Salter, of the Stiper Stones (p. 50); whilst the Redonia of Rouault has its representative in the British form (fig. 3. p. 50); and the Ribeiria pholadiformis, Sharpe,

* I have the authority of M. Fridolin Sandberger to state, that he knows of none of the Upper Silurian trilobites of Bohemia in the Devonian rocks of the Rhine.

† Barrande on the Silurian Brachiopods of Bohemia, in Haidinger's Naturwissensch. Abhandl. 1847, vol. i.

‡ 'Système Silurien de la Bohème,' vol. i.

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which characterizes the Lower Silurian of Portugal, and resembles our fossil Redonia? complanata (p. 50), makes its first appearance in Bohemia in this stage. Let us also mark, that here, as in Shropshire, graptolites and orthoceratites are associated in the same zone with the above-mentioned mollusca, and that one of the Bohemian orthoceratites has a striated surface similar to our Orthoceras Avelinii (p. 50. fig. 4).

M. Barrande has also met with another link which binds together the northern type of Russia, Scandinavia, and England with that of Bohemia, in a species of large Orthoceras of the group O. duplex (p. 377), so eminently characteristic of this age in the North of Europe. He has, in short, detected about sixty species in this zone, a portion of which he has tabulated*. Among these fossils we perceive the remarkable cephalopod with step-like septa, the Bathmoceras, Barrande, together with a large Ogygia, the Calymene Arago, and Bellerophon bilobatus; the last, which is so typical of these rocks in Britain and France, being very abundant. It is also worthy of notice, that the Agnostus tardus, Barr., which had hitherto been recognized in the upper division only of stage D, makes its first appearance in these much older beds. Here also appears, for the first time, the Graptolites priodon (colonus, Barr.), which does not play the same part as in Britain by living on through so long a lapse of time (see p. 139); for, whilst in Wales and Shropshire the latter was in existence from the period when the slaty rocks of Snowdon were formed to the time of the Ludlow deposit, this same fossil in Bohemia, with all its congeners, reappears no more above the stage E of the Bohemian basin. Again, among the fossils of this zone there are Orthidæ of three species, a small Euomphalus?, E. primus, Barr., or rather belonging to the many-whorled genus Ophileta of Sutherlandshire and Canada, several species of Cystideæ and Ophiuridæ, with Encrinites, as well as forms of the little entomostracite Beyrichia, which characterizes vast breadths of Upper and Lower Silurian rocks in many countries, even in the Arctic Regions. Already, therefore, in this very ancient stage, we find many of the types which range through the whole Silurian system!

The overlying stages of the great Lower Silurian deposit of Bohemia, or the four upper subdivisions of the group D of Barrande, correspond on the whole to the remainder of the Llandeilo Flags and all the Caradoc formation. But the same mineral characters are so persistent throughout the series of numerous bands of quartzite, and similar courses of schist are so repeatedly interlaced with them from the base to the summit, whilst so many fossils are common to the whole, that it has not been found practicable to mark the same distinctions as in Britain. Among the fossils which most prevail may be mentioned

* Bull. Soc. Géol. Fr. 2 sér. vol. xiii. p. 532.

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Beyrichia Bohemica, Acidaspis Buchii, Placoparia Zippei, Theca elegans, and Ribeiria pholadiformis; the latter having lived on from the earliest formed strata of this group (D).

Let me here add a few more words on some striking features of the organic remains of this Bohemian basin. Among the graptolites the G. priodon (Ludensis, Sil. Syst.), which in England is found in all the Silurian rocks, is beautifully preserved,—its smaller end being incurved. Of corals there occur quite as many Silurian forms as are known in England. The Cystideæ of the Lower Silurian (stage D of Barrande) are occasionally of great size, and some of them, like the Echino-encrinites of Scandinavia and Russia, ascend into the stage E, or Upper Silurian.

The profusion of chambered shells in the basin of Prague has enabled M. Barrande to trace many gradations between the generic types Gomphoceras, Phragmoceras, Trochoceras, Cyrtoceras, &c.; and in the centre of two specimens of Orthoceras he has detected animal matter in the state of adipocire! These bodies are, therefore, he justly considers, the oldest *mummies* ever exhumed; since they occur in Lower Silurian rocks with Trinuclei! The most ancient Nautilus yet found is probably the N. tyrannus, Barr., a huge form of a genus which the author has traced through all its stages of growth. There are some Goniatites, of forms approaching Nautilus; but no species—not even in the very highest strata near Prague—is a known Devonian type.

Besides the genera of trilobites enumerated as occurring in the primordial or lowest zone, that band also contains the Hydrocephalus, so named by Barrande from its inflated head, and the Arionellus, a large flat form, which M. Angelin has recognized in the same zone in Sweden. In the succeeding mass of the Lower Silurian, or stage D of the author, is found the Beyrichia lata, common also to Sweden and America. The Acidaspis Buchii has been described also by M. Bertrand Geslin from rocks of this age near Nantes; whilst other Entomostraca, chiefly bivalved (of which there are about twenty species), range from the lowest to the highest of the Upper Silurian limestones.

Space does not permit of an examination of the analogies and identities prevailing among the brachiopods and gasteropods of the basin of Prague as compared with those of Silurian age in other countries. Suffice it to say, that, when fully elaborated, the whole of the fossils will probably amount, under the discrimination of M. Barrande, to upwards of 2000 species!*

Other results of the researches into the contents of the Bohemian basin show just those agreements in the general distribution of life and the peculiarities of local arrangement which are found in all synchronous

* Geologists will do well to consult the beautiful suite of Silurian fossils from Bohemia in the British Museum, as collected, classified, and arranged by M. Barrande.

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deposits. Thus, the Pterygoti in Britain ascend from the Llandovery to the Ludlow rocks, and in Bohemia they range upwards from the stage E, or the representative of the Wenlock formation.

Again, the Asterida, or Star-fishes, which are rare in what may be called the Llandeilo rocks, or Barrande's subdivision D^1, become conspicuous in the higher stage or Caradoc, D^4. They have the same range in Britain and Canada.

Notwithstanding their strict conformity to each other, the Lower and Upper Silurian rocks of Bohemia are supposed to be more sharply separated from each other by fossils than in the wider area of the British Isles. This fact may to a great extent be explained by an appeal to the usual phenomenon of a clear separation of types *wherever a limited tract only is surveyed.*

But here we have another cause, by which M. Barrande accounts satisfactorily for the specific separation, in this tract, of the animals of his three Silurian zones. He shows, that, after the accumulation of what he calls the primordial fauna, the sea-bottom of this region was powerfully disturbed by the eruption of porphyries. Again, after the completion of his second zone, or at the close of the older Silurian period, other igneous rocks (greenstones, trap, &c.) were so copiously and repeatedly evolved, as to account for the destruction of nearly all the animals then living in this area; the creatures which were enabled to exist and live on during such turbulent conditions being for the most part Graptolites.

Yet even under this point of view, the author of the 'Bassin Silurien de la Bohème' has proved, that not less than sixty species of fossils are common to his stages D and E. Thus, when the observer is working his way up through the Lower Silurian schists and quartzites of the stage D, with their Orthidæ and Trinuclei, he meets unexpectedly in them with intercalated bands of dark shale, mineralogically similar to those of the superior stage, and in which, out of sixty-seven discovered species, sixty are forms that characterize the Upper Silurian band E. This is the more remarkable, as the fossils otherwise known in the stage D are by no means similar to those of the overlying rocks.

M. Barrande, broaching an original theory, has suggested, that these schists, so insulated among the older strata, may be regarded as having been the seats of "colonies" of animals which, existing in some other part of the world whilst the Lower Silurian fauna prevailed in Bohemia, were carried to these spots by currents, and thus for a time inhabited the region, before the more general introduction of exotic species at a subsequent period.

Some geologists would endeavour to explain the fact by simply showing that fossil animals are frequently associated with particular conditions, disappearing and reappearing with changes of the sea-bottom. The

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only difference between this view and that of M. Barrande is, that he considers his ancient colony to have migrated from remote seas, where his third or Upper Silurian fauna already flourished; whilst, for my own part, I rather prefer to consider them as distinct and separate appearances of similar types in the same tract; the first of them having, so to speak, failed to establish themselves on the spot, the second having acquired a fuller development upon the subsequent reappearance of these animals. But whether we apply the ingenious speculation of M. Barrande or not, the alternation is manifest, and *the Lower and Upper Silurian rocks are undeniably linked together through an interchange of a considerable number of their respective fossils.*

Before I take leave of this rich continental centre of Silurian life, which my eminent friend has rendered so classical, let me invite the attention of the reader to one salient proof of his acumen and sagacity as a naturalist. Every one knows that living crustaceans, from the king crab (Limulus) and lobster downwards, proceed from eggs; and before reaching maturity, many of them, even of the higher grades, are known to pass through a metamorphosis. Now, M. Barrande has discovered, after examining multitudes of specimens, that the trilobite or earliest crustacean underwent a similar metamorphosis from the embryo to the adult state, and passed through many changes of form. In the genus Sao, for example, he has distinguished no less than eighteen stages of development of the same species, each stage being marked by an addition to the thoracic ribs of the animal; and he has thus taught us, by true natural proofs, that several so-called genera and many species named by contemporary authors really belong to this one creature*. The same analysis of forms has, indeed, been extended by the author to other and higher deposits of the Silurian system; for he has indicated twenty-two changes in his beautiful new species Arethusina Koninckii of the stage E; and altogether he has found the phenomenon to hold good in thirty-four species of trilobites in the Lower and Upper Silurian strata; there being seven metamorphoses in the genus Trinucleus alone. He has even followed out his subject into other families, and has traced the fossil Nautilus from the egg, through twenty variations of form, to its completion with a perfect aperture to the shell.

In a word, the work of M. Barrande will convince every one who studies it, that we have now obtained quite as clear an insight into the earliest stages of life yet recognized upon the globe, as into the succession of those younger deposits, the secrets of which are so much more easily wrung from the less indurated stony records of nature.

* See particularly Corda, 'Prodrom. einer Monog. der Böhmische Trilobiten,' in which the species Sao hirsuta, Barr., has been divided into no less than ten genera, and these again subdivided into eighteen species!

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Paleozoic Rocks (Silurian, Devonian, Carboniferous, and Permian) of Thuringia, Franconia, Saxony, and the adjacent Principalities.*—The older sedimentary formations occupy a considerable region on the north-western flank of that devious chain of granitic, gneissose, and other crystalline rocks, which, ranging from north-east to south-west, divides Saxony from Austria, and trends into the Fichtel-gebirge of Bavaria. From that chain, the deposits in question descend into and spread over a broad and comparatively low, undulating tract, which in its central part is cut through transversely by the river Saal, as it flows from Hof on the south-east to Saalfeld on the north-west. On their western boundary, these sedimentary rocks again constitute some of the lofty eminences of the Southern Thüringerwald; the whole succession under consideration having a dominant strike from south-west to north-east. In this way the younger strata may be said to occupy a broad trough, ranging lengthwise from Ronneburg and Gera on the north-east, by Schleitz, Plauen, and Hof, to Upper Franconia on the south-west; whilst the older rocks of the series, rising up on either side, are often in a highly metamorphic state, but chiefly on the south-eastern flank of the depression.

The first effort to co-ordinate the various sedimentary rocks of this region with their equivalents in the Rhenish provinces and the British Isles was made in the year 1839 by Professor Sedgwick and myself†. We commenced our survey by examining the mountainous elevations or old greywacke of the South Thüringerwald, and thence extended our observations to the younger shelly limestones of Upper Franconia, wherein Count Münster had collected his transition fossils. As the result, we indicated that which has proved to be the true general succession. We spoke, for example, of a slaty greywacke with greenish slate, and quartzose flagstones and grits like those of the Longmynd; of quartzites in roofing slates with a greenish tinge (Schwartzburg, &c.), that reminded us of the lower slates of Cumberland and Westmoreland. The whole of them were said to exhibit great undulations, but with a prevalent dip to the south-east—to be powerfully affected by a slaty cleavage—and to be surmounted by subcrystalline limestones with alum slate (pyritous shale of Doschnitz, &c.). These, again, were described as covered by other grey schists and greywacke, containing also courses of limestone; and all such beds disappeared, we said, under more earthy and arenaceous strata, resembling the Devonian rocks of the Rhenish provinces. Finding, however, no fossils except encrinites in the lower part of these rocks, we could assign to them no more definite place than that they were probably of the age of the slates of the Ardennes. On

* For details of the Permian rocks of these tracts, see p. 331 *et seq.*

† Trans. Geol. Soc. Lond., 2nd ser., vol. vi. p. 296.

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the other hand, we considered the fossiliferous limestones of Franconia (Elbersreuth, Hof, Gattendorf, &c.), which are replete with Clymeniæ, Goniatites, and Orthoceratites, as being unequivocally of Devonian age; and, lastly, by actual sections, we confirmed the view of Count Münster derived from fossils only, and showed that the limestones and associated schists of Trogenau, Regnitz Losau, and Würlitz near Hof, were truly of the age of the Carboniferous or Mountain Limestone*.

In calling attention to this view of succession, which, in a recent visit with Professor Morris, I found to be substantially correct, it is by no means contended that Professor Sedgwick and myself did more than offer a general suggestion; for at that time, not only was there no true geological sketch of this complicated country, but not even any ordinary geographical map which could be depended on. In the nineteen years which have since elapsed, good trigonometrical surveys have been made of large portions of the region; able geologists of Saxony and Meiningen have likewise constructed geological maps, and have described many fossils entirely unknown in former days.

Thus, Professors Naumann, Cotta, and Geinitz, in Saxony, and M. Richter of Saalfeld in Meiningen, have elaborately worked out the demarcation of the mineral masses of which these old rocks are composed, and, some having been found to contain graptolites, trilobites, and other ancient fossils, such inferior greywacke has very properly been referred by those authorities to the Lower Silurian†. With this view I quite agree, guarding the definition of the word "Lower Silurian" by explaining, that some of the black schists of this region which contain graptolites, may be of the age of that zone in Bohemia, which forms the base of the Upper Silurian of M. Barrande.

The following, therefore, may be taken as a view of the succession, which completes the first sketch by Sedgwick and myself.

1. Ancient rocks of the Thüringerwald, consisting of greenish talcose schists with white quartz veins, which in former times afforded some gold. They range from Steinheide by Igleahieb, or from south-west to north-east, in association with certain bands of ferruginous and purple-coloured greywacke,

* The fossils collected in these limestones were Productus punctatus, P. antiquatus, P. sublævis, P. pustulosus, a large Orthis near to O. crenistria, Phill., Chonetes papilionacea, Euomphalus pentangulatus, and several corals of the genera Syringopora, Cyathophyllum, &c.;—a perfectly carboniferous assemblage.

† I must not omit to add to this list the name of M. Engelhardt of Ober-Steinach, who has made a large collection of fossils, some of which are manifestly of Lower Silurian, and others of Devonian age. The strata near that place are so dislocated and in great part inverted, that I can well understand how that gentleman, from whom I experienced every courtesy when I visited Steinach, should have been led to indicate an order of strata, whereby the rocks which are really Devonian were placed under the Lower Silurian greywacke. The formations referred by him to the Upper Silurian, under the names of Wenlock, Aymestry, Ludlow, &c. (Zeit. Deutsch. Geol. Gesellsch. Berlin, vol. iv. p. 234), are for the most part Devonian, as proved by fossils; but, not relying on my own judgment only, I obtained the opinion of M. Barrande, which confirmed my own views.

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not unlike the bottom rocks of the British sections described in the second chapter of this work. These masses occupy the highest grounds of the Oberland of Meiningen, attaining an elevation of nearly 3000 English feet above the sea. 2. The beds of this lofty plateau fold over both to the north-west and south-east, and are throughout affected by a slaty cleavage, which extends to all the overlying formations. As the planes of this cleavage, usually plunging to the north-west at a high angle, are dominant, and often obliterate the lines of true bedding, they have misled some observers with respect to the physical succession of the strata.

Attentive observation, however, shows that, rolling over in undulations to the south-east, the above rocks ("Grüne Grauwacke" of Richter), containing the fucoid, Phycodes circinnatum, Richter, and the pygidium of a trilobite, are overlaid by the group which Richter terms "Graue Grauwacke." The latter is composed of much slate with hard siliceous sandstone, courses of limestone, and some alum schists; one portion of the slaty rocks being extensively quarried for the manufacture of slate pencils (Criffelstein). The lower beds exhibit fine examples of fucoids, among which are the Fucoides Alleghaniensis, together with Myrianites, and the (graptolites?) Cladograpsus nereitarum, Nereograpsus Sedgwicki, and N. Cambrensis (Nereites*, Sil. Syst.). The upper beds especially contain graptolites, orthoceratites, and some forms of trilobites. Of the truth of this succession I convinced myself by examining, with M. Engelhardt and Professor Morris, that portion of the section of Ober-Steinach which pertains to the Silurian rocks. A species of trilobite found by M. Engelhardt approaches near to, if it be not identical with, Ogygia (Asaphus) Buchii, whilst a form of Maclurea collected by M. Richter closely resembles the M. magna, Hall; and, as some of the worm-like bodies (Nereites), and several of the graptolites, both double and single, are not distinguishable from forms known in the British Isles, there can be no doubt, that we have in this slaty group a true equivalent of a Lower Silurian formation, and probably of Llandeilo age.

The positive identity of the Thuringian strata with their equivalents in Britain has been further established by the occurrence, not only of the same species of Annelide or large Nereites, as above noticed (see the woodcut, p. 221), but also by the Protovirgularia dichotoma; specimens of which Richter has detected in Germany, apparently identical with those collected by Sedgwick in the Lammermuir Hills of Scotland.

It would further appear, that there are strata in the Southern Thüringerwald which by their fossils approach to the Caradoc and Lower Llandovery rocks of Britain; for Richter has shown† that, together with Trinucleus, the Phacops Stokesii is present, as well as the Pentamerus oblongus and P. globosus. With these also are the well-known British Lower Silurian fossils, Euomphalus Corndensis, Sil. Syst., Orthis testudinaria, Dalm., O. alternata, Sil. Syst., O. lata, ib., Leptæna sericea, ib., &c., some of which are Lower Llandovery species.

The upper beds of alum slate and flinty slate are principally characterized by graptolites, several of which are species identical with those described by Portlock, Salter, M'Coy, Harkness, Nicol, and myself, chiefly from the Lower Silurian of Britain; and among these, as seen in the work of Geinitz, or identified by M. Richter, are the following: Diplograpsus folium, His.; D. pal-

* M. Geinitz regards these as belonging to the Graptolite family.

† Zeitschr. der Deutschen Geol. Gesell. 1853, p. 489; ib. 1854, p. 275, note.

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meus and D. ovatus, Barr.; D. teretiusculus, His.; Graptolithus priodon (Ludensis, Sil. Syst.); G. Sedgwicki, Portlock; G. Becki, Barr.; G. latus, M'Coy (?); G. spina, Richt.; G. turriculatus, Barr.; G. Nilssoni, Barr.; G. sagittarius, His.; G. colonus, G. Proteus, and Rastrites peregrinus, Barr.*; with some other species common to this region and Bohemia, including the remarkable form Retiolites Geinitzianus, Barr. Several of the graptolites are similar to those of the Silurian deposits of Scandinavia, North America, and other countries.

The researches of M. Richter have, indeed, gone farther, and have enabled us to speculate upon a close approach to the Upper Silurian, if he has not really made known the base of that division. For, among the remains of one of the courses of limestone he has detected Cardiola interrupta, Brod., Acroculia prototypa, Phill., with the Orthoceras styloideum and O. Bohemicum of Barrande, both of which characterize the stage E of that author.

The Silurian rocks of the Thüringerwald and of the Saalfeld tract, which are penetrated at intervals by porphyries and greenstones, are irregularly overlapped, towards their south-eastern flanks, by masses of Devonian age (the "Rothe Grauwacke" of Richter), which will presently be considered. Silurian schists containing graptolites again emerge from beneath younger strata in a series of low undulations far to the east of the lofty, wooded Thüringerwald. The base, in fact, of the low ridges extending from Ronneburg on the north-east, through Schleitz, to Lobenstein on the south-west, is composed of graptolite schists and roofing-slates. Similar rocks reappear in parallel undulations in the environs of Plauen and Hof; and it is probable that considerable portions of the "Thon-Schiefer" of the geological map of Saxony will hereafter be found to belong to the Lower Silurian division.

The exact demarcation of the outline of these Silurian formations, and their separation from all the older unfossiliferous and crystalline strata on the one hand, and from the Devonian rocks on the other, will be a work of no small labour. Their regular order has been repeatedly interfered with by pseudo-volcanic or eruptive masses, which, whether they constitute stratified layers or appear as intrusive bosses, have singularly affected the ordinary sediments. These igneous rocks are, indeed, most accurately laid down on the map by Professor Naumann and his associates. So rapidly does the geologist here proceed from one formation to another, that a single small hill, composed of Lower Silurian schists with graptolites, is often contiguous to the Upper Devonian limestone. These changes are well seen near Schleitz, where the low ridges of black brittle schist, which form the pleasure-grounds of the reigning Prince (Heinrich's Ruhe), are laden with Graptolites,

* See some of these forms of Graptolite, p. 64, and Plates 1 and 12 of this work.

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Orthidæ, and other fossils of Lower Silurian date*; whilst, on the western side of an intervening small hill of eruptive rock, the geologist has before him a limestone charged with Clymeniæ, Cypridinæ, and the very uppermost Devonian fossils! On the whole, however, it may be said, that, although they occupy so broad an area in the lofty tract of the Thüringerwald, the Silurian rocks only make their appearance partially, and within comparatively narrow bounds, in the central portion of that region which has here been designated a vast *undulating trough*. Even then one characteristic band is alone visible, composed of the black schists and slates, extending from Ronneburg by Schleitz, to Lehestein and Lobenstein.

The Devonian rocks of this portion of Germany, previously known to us by the paleontological illustrations of Count Münster, have recently been much better developed by the labours of Geinitz and Richter.

From the densely wooded cover of the lands, it is exceedingly difficult to trace any absolute junction of these Devonian rocks with the subjacent Lower Silurian of the Thüringerwald. That they lie, however, irregularly upon their older neighbours, is manifest from the faithful delineation of their outlines in the geological map of Richter, in which the Devonian, or the "Rothe Grauwacke" of that author, constitutes patches or hummocks only, in relation to a great spread of the more ancient rocks†. That this is their true position, I can now affirm.

The extent to which this Devonian group of Thuringia, Franconia, and Voigtland can be paralleled in its details with that of the Rhenish provinces of Prussia is not yet completely ascertained; for, beginning with what is now usually recognized as the lowest fossiliferous rock of the Rhine, or the "Spirifer Sandstein," I have not been able, any more than in Russia (p. 384), to detect such strata infraposed to the fossiliferous limestones of this region.

* All the Silurian fossils figured from this spot in the work of Prof. Geinitz were previously found by M. Berner, of Schleitz, who had, it appears, detected graptolites in these strata many years before the attention of geologists was called to them.

† See Beitrag zur Palæontologie der Thüringer-Waldes von Reinhard Richter, Dresden and Leipsig, 1848; and Die Versteinerungen der Grauwacken Formation in Sachsen, &c., von Hans Bruno Geinitz, Leipsig, 1853. In the first part of his able work, Prof. Geinitz describes and figures many species of graptolites, before referred to, p. 405; and in the second he adds to these the following Silurian fossils:—Nereograpsus tenuissimus, Emmons; Orthoceras Brongniarti, Troost; O. tenue, Wahlenberg; Leptocheles (Ceratiocaris?) Murchisoni, Agass.; Tentaculites tenuis, Sow.; Pterinea Sowerbyi, M'Coy; Nucula levata, Hall; Cytherina subrecta, Portlock (?); and Orthis callactis, Dalm. These fossils are, however, very obscure, and their identification therefore doubtful. In the Devonian rocks he describes one genus of trilobite (Phacops) only; of chambered shells, 24 species, including Orthoceras, Gomphoceras, and Cyrtoceras; Clymenia, 6; Goniatites, 4; Gasteropods, 8 species; Lamellibranchs, 24 species; Brachiopods, 11—including the universal Atrypa reticularis; of Crinoids, 9 or 10 species; and about 11 kinds of corals are also enumerated.

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The next question then is, can we even divide the Devonian of this region in Central Germany into lower and upper limestones, as was first done in Devonshire, and afterwards in the Rhenish provinces?

This separation has, indeed, been partially made by Geinitz, who places at the bottom of this group certain schists near Ronneburg, which Naumann has identified in several other localities. These schists contain Tentaculites lævigatus, Roemer; T. subconicus, Gein.; with Phacops. Then follow certain limestones near Plauen, Wildenfels, and other localities, including the well-known Elbersreuth, which are also classed as older Devonian. These are characterized by Orthoceras interruptum and O. dimidiatum, Münst., Clymenia lævigata and C. linearis, Münst., corals, and crinoids. Then succeed stratified, igneous rocks, some of which are greenstones, others coarse trappean breccias, and others again finely levigated ash-beds, occasionally calcareous and undistinguishable from the "Schaalstein" of the Rhine (Plauschwitzer-schichten of Naumann). Above these is said to be placed the Clymenia limestone, properly so called, and in which many fossils abound, including Goniatites and several species of Posidonomya (P. inversa and P. regularis, Goldf., &c.), together with a vast profusion of Cypridina serrato-striata, Roemer. Not professing to have worked out the proofs of these subdivisions, I must say, that in those tracts which I have examined, there are no evidences of two Devonian limestones, separated from each other by slaty rocks, as in England and on the Rhine.

In short, I have nowhere seen in Saxony, or the adjacent districts, a full representative of the Eifel limestone, as characterized by its Stringocephali, Calceolæ, &c., overlaid by another which represents the Clymenia rock of England (the Krammenzel-stein of the Rhine). Recently, however, M. Geinitz has detected in the strata inferior to the Cypridina schists the following fossils, all of which are found in the Eifel limestone: viz. Fenestella cervicornis, Edw. and Haime; Stromatopora concentrica, Goldf.; Fenestella subrectangularis, Sandb.; Productus subaculeatus, Murch.; Chonetes minuta, de Kon.; Atrypa (Spirigerina) reticularis, Linn.; Terebratula elongata, Schloth.; and a large species of Phacops. But, as towards the end of this chapter we shall indicate that those two calcareous masses which are so clearly separated in some districts are nearly brought together in others, so is it possible that the divisions partially indicated through their fossils by Geinitz may be established in Voigtland, and that the trappean tuff (schaalstein) of Plauschwitz and other places may, as he believes, separate these two rocks.

However this may be, the ascending order, in several localities, is clear, from a highly fossiliferous and nodular limestone, laden with Cypridinæ, Clymeniæ, Goniatites, and Orthoceratites, and which is clearly Upper Devonian, into associated strata in which land plants begin to appear. The Devonian limestone is surmounted by a copious accumulation of sandstones and schists, occasionally siliceous—the "jüngste grauwacke" of Geinitz, charged with terrestrial vegetable remains. These are sometimes followed by the carboniferous limestone or "kohlen-kalk" with its large Producti, and by other strata which contain a different series of land plants.

Such an ascending order is seen at Hof, on the right bank of the Saal, between the town quarries, replete with Cypridinæ, and an overlying coralline limestone. This succession is more clearly viewed between Gattendorf and

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Troguenau; the intervening space between the Devonian or Clymenia limestone of the former and the Carboniferous or Productus limestone of the latter being occupied by ferruginous greywacke with traces of plants, and by a mass of "kiesel-schiefer," which there occupies the same place as the rock so called by the geologists of the Rhine country*.

Again, in the gorge of the Saal, near Saalfeld, the cliffs, which M. Richter has described in a published section†, expose a magnificent mass of limestones, characterized throughout by Cypridina serrato-striata and C. calcarata, Roem., with other Upper Devonian types, but which offer no evidence whatever of a second limestone between them and the Lower Silurian rocks. Here the same geologist has detected Phacops latifrons, Bronn, P. granulatus, Posidonomya minuta, and P. intercostalis, Roem., with trails of worm-like animals. Here also (no igneous rocks appearing) the ascending order seemed to me to be clear and unequivocal. In spite of the dominant slaty cleavage, the planes of which dip to the north-west, the Cypridina limestones, after those fine convolutions which render the gorge so picturesque, are seen to pass under the mass of red rocks, or "Rothe Grauwacke" of Richter‡, the whole being covered unconformably by terraces of Zechstein.

The lower part of this reddish, sandy, and schistose flagstone is interlaminated with the Cypridina-schiefer, the mass of which immediately succeeds to the limestone; and from this point the beds begin to contain land plants, which augment in quantity and size in the overlying or younger strata. These consist, first of reddish and grey, and then of greenish shale, of considerable thickness, which on the right bank of the Saal extend from the cliffs of Bohlen by the Pfaffenberg to the Kleitsch Hill, and finally, at the foot of the Rothenberg, are surmounted by ferruginous micaceous flagstones, containing a great quantity of fossil plants. I direct particular notice to this section, because it exhibits, more clearly than any other known to me, the extent to which the land vegetation augments as we ascend from the Devonian rocks.

The lowest plants, as discovered by M. Richter in the Cypridina schists, consist, according to Professor Unger, to whom they were referred, of many species belonging to new or undescribed genera, and even to new families. Some of them are considered to be intermediate between Ferns and Equisetaceæ,—others seem to be primitive forms of

* Much confusion may arise, in comparing the local descriptions of German geologists, from the use of mineral terms applied to rocks. Thus, in this region of Thuringia and Saxony, "Kiesel-Schiefer," which here usually designates some of the older Silurian schists and also some Devonian beds, might be strictly applied to the flinty, schistose strata overlying the Cypridina limestone and its greywacke near Hof, and which are unquestionably on the parallel of the so-called "Kiesel-Schiefer" of the Prussian and Hessian geologists—*i. e.* of the date of the lower carboniferous formations.

† Beitr. Palæont. des Thüringer-Waldes, Tab. 1. Dresden, 1848.

‡ I convinced M. Richter of this fact, by closely scrutinizing the section in company with that gentleman.

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Cycads and Conifers, possessing characters of which (says the Professor) no one has as yet had an idea; and one presents such a singular organization, that he terms it the "prototype of the Gymnosperms!" This is the genus Aporoxylon of Unger, a coniferous tree which has only simple wood-cells, without the disks usual in plants of this order. In some of these Conifers the resin even of the wood has been preserved. The above are figured in his last important memoir*, where also are enumerated from the same beds several species of the Calamiteæ;—Haplocalamus, Calymma, Calamopteris, Calamosyrinx; and some of a more solid structure, Calamopitys; a few forms of the genera Cyclopteris, Sphenopteris, Dactylopteris; besides several genera founded on the stems of plants. There is also a Lepidodendron, L. nothum, probably identical with one from Caithness (see p. 290, f. 4).

This section is still further interesting in demonstrating a passage upwards into other and overlying beds beneath the Rothenberg,—viz. into the micaceous sandstones and flagstones, which, on account of their flora, must be classed with the lower carboniferous rocks. Such, for example, are Calamites transitionis, Göpp.; Megaphytum (Rothenbergia) Hollebeni, Cotta; with Knorria, &c.; plants which are well known in the Rhenish provinces of Prussia, where they invariably occupy the lower carboniferous rocks, and never descend, like the group above mentioned, into the Devonian, properly so called. Here, then, on the edge of the Thüringerwald, M. Richter has collected data to prove, by fossil vegetables alone, a succession from the Devonian to the Carboniferous period.

Having called the attention of that author, on the spot, to the importance of applying these facts respecting the distribution of the fossil plants to the tracts between Saalfeld and Schleitz, in parts of which such remains were for the first time observed in a recent excursion†, I now learn from him, that he has considerably extended the area which is occupied by the lower carboniferous rocks in that country, as defined by its terrestrial vegetation‡.

These plant-bearing rocks also occupy a considerable stripe of elevated country at the southern extremity of the Thüringerwald between Sonneberg and Teuschnitz; and they occur in abundance in the gorge

* Beitrag zur Palöontologie des Thüringer-Waldes, by R. Richter and Franz Unger. Denkschr. der Math.-Naturwiss. Classe der Kaiserl. Akad. der Wissenschaften. Band xi. 1856, Vienna.

† The observation was made by M. Richter and Baron von Baumbach, in company with Professor Morris and myself.

‡ The ground between Saalfeld and Schleitz is all laid down in the geological maps of Saxony under one colour, or as older "grauwacke"; whereas a very large portion of it must now be assigned to the *lower carboniferous formation*. When will my valued friends, the mineralogists and geologists of Germany, abandon a word which has led to such endless confusion? I cannot but regret that a work of such ability as that recently issued by Geinitz should bear the title of the 'Fossils of *the* Grauwacke Formation,' under which name he groups together a vast series, including Silurian, Devonian, and even Carboniferous rocks.

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of the Steinach river, north of Köppelsdorf. As they offer a good line of geological demarcation, I strongly urged M. Credner to distinguish this "Jüngste Grauwacke" of my German friends from all its older associates which bear that unmeaning family name. It will, of course, require much accuracy of local observation to draw the line between the plant-bearing rocks of Devonian and those of Carboniferous age*; or rather, it will best become the progressive state of science, not to attempt to mark any definite and rigorous line between them, but to shade off on a map the colour of one rock into that of another; thus imitating the succession of nature, in which there can be no error †.

Such is an outline of the paleozoic succession of the last-mentioned diversified region of Central Germany, the complete elaboration of which calls for the full employment of the able men who are occupied in working out its highly interesting features. A slight allusion only has been made to the south-eastern flank of the great undulating trough of Plauen, Schleitz, and Hof; for, although Naumann and his associates have shown in their maps, that older and more crystalline rocks appear, we have yet to learn how much of their primary clay-slate, or "thon-schiefer," is to be abstracted from the unfossiliferous rocks, and grouped with the lower members of the series we have been considering ‡. Other

* After the first edition was published, M. Credner completed his map of the Southern Thüringerwald, and separated the older from the younger "grauwacke"; but he has not divided the latter into "Upper Devonian" and "Lower Carboniferous," according to the new classification which I have endeavoured to introduce.

† At the southern end of the Thüringerwald, Professor Morris and myself partially examined, in company with M. Büttner of Kronach, a zone of coal-measures containing some irregular seams of coal, and exhibiting a rich fossil flora. It flanks the loftier so-called "grauwacke" chain of the Thüringerwald (Köppelsdorf, &c.), and is interposed between it and the Roth-liegende. This coal formation rises out from beneath a vast mass of inclined beds of Roth-liegende, not less than from 1500 to 2000 feet thick (Stockheim, Neuhaus, &c.). As the coal and Roth-liegende are there, as in Gotha, followed by copper slate, zechstein, and a very full development of the Bunter Sandstein (which at Kronach occupies noble escarpments, and is manifestly divided into a whitish lower, and a red upper sandstone), this district is well worthy of a special treatise to develope the features of the Permian group with its relations to the coal beneath, and to the lower Bunter Sandstein above it.

The general relations of these overlying deposits to the so-called "grauwacke" rocks of the Thuringian mountains, are seen in the southern sheet of the geological map of the Thüringerwald by M. Credner. In classifying the igneous rocks of the Thüringerwald, M. Credner believes that the granites, with hypersthene rocks, &c., have caused the great metamorphism of those strata, which, in Southern Thuringia, I have described as Lower Silurian, &c., but which, in the northern parts of the forest where granite abounds, become mica schists, &c. The greenstones and amygdaloids of the tract are associated, according to Credner, with carboniferous rocks; and the two porphyries of the region, the one containing quartz, and the other being without it, are connected by that good practical observer with the period of the Roth-liegende; the former, which is the older, being traversed by the "*quarz-freier*" porphyry.

‡ In travelling from Plauen to Franzenbad, it seemed to me impracticable to

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inquirers may seek to ascertain to what extent many of these ancient schists and slates, evidently of sedimentary origin, have been converted into mica schists, and even into the metalliferous so-called "gneiss," amid which the illustrious Werner himself taught his lessons at Freiberg.

It would seem presumptuous that a passing geologist should here hazard an opinion antagonistic to long-received ideas. Still I venture to state, that much of the so-called primitive gneiss in the plateaux around Freiberg is of a very different age to the most ancient gneiss of Scotland and Scandinavia. I would indeed suggest, that those portions of it which are separated by way-boards, and exhibit several of the features of bedding and jointing of aqueous deposits, will, like the quartz rocks and mica schists of the north-western region of Scotland (p. 196), prove to be of no higher antiquity than the lower members of the sedimentary formations under review.

In the mean time, if we reason upon the fact, that this region contains no Upper Silurian rocks (abstracting from that category certain graptolite schists, which may be considered their base), we may surmise that it was raised above the waters, and constituted dry land during a long period, and was afterwards depressed to great depths, to receive accumulations of the Devonian era, at a period when, and in localities where, the bottom of the sea was powerfully agitated by volcanic action.

This country also contains clear evidences of a phenomenon to which Professor Sedgwick and myself called attention in 1839, viz. that whilst the older "grauwacke," now known to be Lower Silurian, as well as the Devonian and Lower Carboniferous series, have partaken of the same movements of elevation, contortion, and dislocation, all these rocks have been abruptly separated from the upper coal-fields.

This great physical rupture, which pervaded Germany and France, and has been duly noticed by M. Elie de Beaumont, has, however, its well-defined limits even in Europe; for, grand as it may be, the

separate geologically and physically the "thon-schiefer" or glossy shillat of that district from the contiguous graptolite schist of Plauen. In fact, the rocks on either bank of the Elster are mineralogically the same, and have similar bedding, joints, and cleavage; the latter plunging to the north-west. The discovery of Silurian fossils in the "greywacke," which rises into the hills on the flanks of the Erzgebirge, would remove all doubt as to the age of the "thon-schiefer."

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phenomenon is local only, and has not extended to Russia on the east, or Britain on the west.

The reader must also be reminded, that the region of Central Germany, which has been most adverted to, exhibits clearly the intimate dependence of physical outline on eruptive igneous agency. In the Thüringerwald, and, as will presently be shown, in the Harz, all these older rocks, terminating with the Lower Carboniferous strata, which have the original impress of a strike from N.E. to S.W., were so affected by the grand eruptions of porphyry and other igneous masses which prevailed in the earlier part of the Permian era, that both chains then acquired directions at right angles to the original strike of their oldest strata.

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CHAPTER XVI.

PALEOZOIC ROCKS OF THE HARZ, THE RHENISH PROVINCES OF PRUSSIA, AND BELGIUM.

UPPER SILURIAN, DEVONIAN, AND CARBONIFEROUS ROCKS OF THE HARZ.—DEVONIAN AND CARBONIFEROUS ROCKS OF THE RHINE AND ITS AFFLUENTS.—DEVONIAN AND CARBONIFEROUS DEPOSITS OF WESTPHALIA AND BELGIUM.

IN advancing westwards from Central Germany by the Harz* to the Rhenish provinces of Prussia, the geologist loses all traces of the Lower Silurian rocks of Bohemia, Saxony, and the Thüringerwald, whilst, with some Upper Silurian, the Devonian and Carboniferous deposits become vastly more expanded. Yet, with this absence of the oldest fossiliferous strata, the regions under consideration present as venerable an exterior, and contain rocks possessing quite as crystalline a structure, as those of which we have just taken leave. For, if we first glance at the range of the Harz,—that shrine at which many poets have worshipped Nature in her wondrous freaks, and where the German geologist long regarded his old "Grauwacke" as a mass, the order and age of which could never be defined,—its chief portions were first ascertained by Sedgwick and myself † to be of no more remote antiquity than the Devonian era.

The giant Brocken itself, sanctified by many an ancient legend, is a mere upstart, compared with the surrounding eruptive masses,

* I first visited the Harz in 1830, and secondly in 1839,—on both occasions in company with Prof. Sedgwick, and the general order of the chain, which we published in 1839, has proved substantially correct,—subject, always, to that reformed interpretation of the exact relative value of the various sedimentary rocks which is now applied to this tract and the Rhenish provinces. In referring to that instructive work, the Palæontographica of Dunker and Hermann von Meyer, the reader, in obtaining much information respecting the fossils of the Harz, as described by M. Adolf Roemer, will perceive, at p. 71, Band 2. lief. 2, how inverted and confused the order of succession appears. My next visit was in 1854, when Prof. Morris was my companion (see Quart. Journ. Geol. Soc. Lond. vol. xi. p. 409); and my last excursion to the same tract was in 1857, accompanied by Mr. Rupert Jones. On my own part I am bound to state, that the doubt expressed in a note, p. 362, of the first edition of this work, concerning the existence of Upper Silurian rocks in the Harz, has now been removed, and that in any fresh issue of the Geological Map of Europe, I will endeavour to represent the existence in a rude manner (if the small scale admit of it) of Silurian, as well as of Devonian and Carboniferous rocks in the Harz.

† See Trans. Geol. Soc. Lond. new ser. vol. vi. p. 283, &c.

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which disturbed the bottom of the primeval sea. That mountain is composed of two kinds of granite, which, having burst forth long after the slaty rocks of carboniferous age had been accumulated, has through ages of decomposition been arranged into those chaotic piles or "felsen-meere," so graphically described by Leopold von Buch. Again, subsequent outbursts of porphyry, during the accumulation of the Permian deposits, were also manifestations of the subterranean forces which produced the last great elevation of the Harz, and gave to the chain as well as the surrounding secondary formations their present outline. For, unlike the prevalent north-east and south-west *alinement* of the older rocks in most parts of Europe, the geographical direction of the Harz is from north-west to south-east; and thus, like that of the Thüringerwald, as before noticed, its appearance upon a map is not derived from its ancient mineral nucleus, but from the unconformable and enveloping younger strata.

Just as many of the slaty fossiliferous rocks and limestones of the Harz are known to be of the same age as those of Devonshire (the Coccosteus of the Scottish Old Red having been found associated therewith), so another suggestion* of my colleague and myself has been verified, and the eastern rocks of these hills are now proved to be of older date. In the tracts around Harzgerode, and in spots near Ilsenburg, as well as in the Lauther-thal in the Western Harz, fossils have been found by M. Bischof, M. Jasche, and M. Adolf Roemer, which leave no doubt that these districts are occupied by Upper Silurian rocks. For, although the fossils of these tracts are nearly all of species unknown in Britain, they belong, as a whole, to Barrande's uppermost Silurian zone of Bohemia.

Having elsewhere shown† the general relations of the strata which I considered to be of Upper Silurian age in the Eastern Harz, I would only add, that on revisiting that tract last summer, accompanied by Mr. Rupert Jones, I was confirmed in the accuracy of the view. It is, I reaffirm, quite true, that the schistose rocks with intercalated fossiliferous limestones near Mägdesprung, Harzgerode, and Alexis Baden rise out conformably from beneath a vast thickness of superincumbent strata which, ranging towards Blankenrode, and dipping to the east, must be considered of Devonian age.

* Trans. Geol. Soc. Lond. 2 ser. vol. vi. p. 300.
† Quart. Journ. Geol. Soc. Lond. vol. xi. p. 431.

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The fossils of these underlying rocks, many of which had been previously figured by Ad. Roemer*, have been recently well compared and identified by C. Giebel of Halle†. They consist, according to the latter, of trilobites of the following eight genera,—Harpes, Proetus, Cyphaspis, Phacops, Dalmannia, Lichas, Acidaspis, and Bronteus. On the whole, these crustaceans, though bearing a very close resemblance to those of the Upper Silurian of Prague, are not, in the opinion of M. Giebel, absolutely identical. An Orthoceras and a Serpulites are also of new species. The genus Capulus gives 13 species; Tentaculites, 2 species; Pterinea, 2 species; Lima, Venus, and Nucula, each 1 species; Spirifer, 9 species; Atrypa, 2 species; Rhynchonella, 8 species, including the well-known R. Wilsoni; Pentamerus, 3 species, including P. Knightii, Sil. Syst., and P. galeatus, Dalm.; Orthis, 3 species; Strophomena depressa, Dalm., and another species; Leptæna, 5 species; Chonetes, 1 species; Discina, 3 species. The Crinoids are, Actinocrinus lævis, Mill., and Rhodocrinus, sp. indet. The Zoophytes are of the genera Retepora, Aulopora, Pleurodictyum, Palæocyclus, Cyathophyllum, Alveolites, Dania, Chætetes, Beaumontia, with Graptolithus. Besides these fossils, three undescribed species of fishes and three or four species of plants are enumerated, one of which is of large size; but whether these latter bodies are of land or marine origin has not been determined.

In his conclusion respecting the age of the 96 fossils which he specifies, M. Giebel makes the following classification. Of decided Devonian species, or those known in other places, there are five species only, and two others which are common to Silurian and Devonian; whilst eighteen are identified as Upper Silurian types, chiefly those of Bohemia. When we add to these data the striking fact, that a Graptolite has been found by M. Bischof in the slaty schists east of Harzgerode, and that M. Ad. Roemer has detected the Graptolithus priodon, Bronn, with other species of that genus in the slaty schists of the Western Harz and in other parts‡, there can no longer be any doubt that, although their limits are still undefined on any map, the Upper Silurian rocks have a real existence in this chain. A large portion therefore of the tracts laid down as *Culm* in the Geological Map of the Harz by M. Adolf Roemer, must, as that author has candidly stated, be changed to Silurian, whilst other parts of the so-called Culm, of which, however, there are real representatives, will pass into the Devonian group. Besides the underlying Upper Silurian rocks, the hill of the Rammelsberg near Goslar is known to be of the oldest Devonian age (*i. e.* Spirifer-Sandstein), whilst the limestones and iron-ores around Elbingerode, and certain masses in the Lauterthal, at Abtenau, &c., are well proved by their fossils to be of the Middle

* Dunker and von Meyer, Palæontographh. Band 2.

† Zeitschrift für die gesammten Naturwissenschaften, Jan. 1858, no. 1, Halle.

‡ Graptolithen am Harze, von Prof. Fr. Ad. Roemer. Leonhard und Bronn's Neues Jahrbuch, 1855, p. 540, plate vii.

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Devonian or Eifelian age*. These are succeeded, first by Upper Devonian and next by slaty masses, formerly included in the "grauwacke" of the Germans, but which Sedgwick and myself first identified with the Lower Carboniferous of Britain, and notably with the *Culm* fields of Devonshire. Referring to our old memoir† for the establishment of that identification, I may say that many years must still elapse before the demarcation between these deposits can be even approximately defined in a region so replete with disturbances, and in which fossils are detected at wide intervals only.

In truth, through the combination of many disturbing causes, the chain of the Harz has literally been riven into detached fragments, the relative age of which can very rarely be proved by order of superposition, and can be interpreted only through a close examination of the organic remains of each broken mass. In the Rhenish provinces, on the contrary, though large portions of their strata are infinitely contorted and broken, and sometimes even inverted, the Northern or Westphalian frontier exhibits a perfect and complete succession of formations in their normal, ascending order. The reader's attention will therefore be now directed to that region.

Paleozoic Rocks of the Rhenish Provinces of Prussia and of Belgium.—The convoluted and broken rocks presenting such an antique slaty aspect, and which, crowned with castles, form the chief features of the gorges of the Rhine and the Moselle, exhibit nowhere any fossiliferous band so old as the Upper Silurian of the Harz. This remark applies to all the territory on the right bank of the Rhine, from the Taunus mountains on the south-east, to the coal-fields east of Dusseldorf on the north-west, and also to a large portion of Belgium. This vast tract, of formerly undivided "Grauwacke," including the Duchy of Nassau, and having its northern frontier in Westphalia, is bounded on the east by the secondary rocks of Hessia, which range southwards by Marburg and Giessen to Frankfort. On the left bank of the Rhine, the same upward succession occurs between the Lower Devonian rocks of the Hundsrück on the south-east, and the coal tracts of Aix-la-Chapelle and Belgium on the north-west. It is only by deflecting westward into the mountainous tract of the Ardennes, that we meet with those older slaty rocks rising from beneath all the other deposits, to which allusion will presently be made.

Although this view of the age of the Rhenish strata has for some

* See Quart. Journ. Geol. Soc. Lond. vol. xi. p. 439.
† See Sedgwick and Murchison, Trans. Geol. Soc. Lond. 2 ser. vol. vi. p. 235, &c. 1839.

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years prevailed among scientific men, it is right to explain how it has happened, that English geologists*, who, in the year 1839, applied to these Rhenish rocks the classification they had worked out in their own country, and thus changed the views of their precursors, should in their turn have seen reason to admit the value of certain important corrections made by their successors.

The clear general views of the Nestor of continental geologists, d'Omalius d'Halloy †, the remarkable work and map of Dumont, as well as the previous labours of Prussian geologists, including the maps of Leopold von Buch, Hoffmann, von Dechen, and Oeynhausen, unquestionably led the way in the succession of efforts through which our present knowledge has been obtained. After the publication of the above works, Professor Sedgwick and myself endeavoured to show that, like Devonshire and Cornwall, the Rhenish provinces contained a great mass of those strata, intermediate between the Silurian and Carboniferous deposits, which we had called Devonian; the equivalent of the Old Red Sandstone of Scotland and Herefordshire. Our contemporaries have admitted that, in our excursion of one long summer in Germany, we succeeded in proving the existence of such an intermediate series in Belgium, Prussia, Franconia, and the Harz; and also in showing how, on the right bank of the Rhine, the uppermost "grauwacke" was divisible into Lower Carboniferous and Upper Devonian rocks. Misled, however, by our interpretation of some of the lowest fossils (for at that time the Lower Devonian forms were only partially known, and those which had been obtained were not rigidly examined), we adopted the belief, that the inferior "fossiliferous grauwacke," or that which has since been called the "Spirifer-Sandstein" of the Rhine, might be an equivalent of the uppermost Silurian. I have, however, been long convinced, through the paleontological labours of Ferdinand Roemer and the brothers Sandberger, that the types of the lower Rhenish subdivision are quite distinct from those of the Ludlow Rock, and even of the Tilestones, and are in perfect harmony with the lowest Devonian group of various countries. In admitting this amount of former misapprehension, let me say, however, that the sections of Sedgwick and myself, representing the succession of the mineral masses, have proved to be correct. In the superior portions of the group, however, now recognized as Devonian, the geologists and paleontologists of Prussia, Nassau, and Belgium have made subdivisions, both mineralogical and zoological, which it is essential to notice.

* See Sedgwick and Murchison, Trans. Geol. Soc. Lond. vol. vi. p. 211.

† See the Geological Map of France and Belgium prepared by M. d'Omalius d'Halloy in the time of the first Napoleon.

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In two recent visits to our old ground, it is satisfactory to have ascertained that all the knowledge acquired since 1839, when the first survey was made, has but confirmed and completed that identification of the rocks of the Rhenish provinces with those of Devonshire, which was then proposed by my colleague and myself. For, it now appears that not some only, as we thought, but *all* the paleozoic strata of Devon have their equivalents on the banks of the Rhine and in Belgium. So that, in starting from the North Foreland of the Bristol Channel, and ascending into the heart of the culm- or coal-fields of Devon, as described p. 294, the geologist has really before him the successive representatives of the several Rhenish and Belgian deposits.

The reader who may refer back to the sixth volume of the 'Trans. Geol. Soc. Lond.,' p. 252, will, therefore, understand that all the Rhenish ground which is described or coloured in the map and sections as Upper Silurian, has been long since classed with the Devonian rocks. In their admirable descriptions of the Devonian fossils, MM. d'Archiac and de Verneuil have but to add the one plate of the so-called Silurian fossils to their thirteen plates of true Devonian types, and all the general features of our labours are in agreement with subsequent observations.

In truth, if the field geologist makes his survey faithfully, and establishes a correct order of superposition, his physical facts will always be found to coincide with the zoological evidence. Of this the Rhenish provinces and Belgium have afforded the best illustrations; for, notwithstanding the opinion of my distinguished contemporary, M. Dumont, who has too much undervalued fossil evidence, it is essentially the study of organic remains which has led to the clear subdivision of the vast mass of older rocks, which were there formerly merged under the term "Grauwacke." The authority of M. de Koninck will in the sequel be cited in support of views similar to my own.

Ascending Series in the Rhenish Provinces and Belgium.—The slaty masses of the Ardennes, or the oldest rocks of the region ("Terrain Ardennais" of Dumont), may probably be considered Lower Silurian; for, though their fossils are very rare and obscure, they are unconformably surmounted by the lowest Devonian strata; thus leaving no place for the Upper Silurian rocks.

M. Hébert* has indeed shown, that certain fossils of the rocks (for the most part very imperfect), in which I formerly observed Homalonoti and traces of shells, then thought to be Silurian, are similar to those of Nehou in Normandy, and hence that the beds which immediately cover the fossil-bearing slates of the Ardennes are really the base of all the Devonian rocks. This conclusion is in unison with the belief expressed to me by my distinguished friend H. von Dechen, so competent a judge

* See Bull. Soc. Géol. de France, deux. sér. vol. xii. p. 1165.

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of the relative age of all the rock-masses of this region, and, as will presently be seen, is amply sustained by M. de Koninck.

Neither in the gorges of the Rhine between Bingen and the mouth of the Lahn, where the rocks have been highly contorted and much subjected to a crystalline slaty cleavage, nor in the quartzose ranges of the Taunus and the Hundsrück, has any one been able to detect true Silurian fossils. On the contrary, the recent identification of the limestone of Stromberg on the south edge of the Hundsrück with the Eifel limestone*, and the discovery by Fridolin Sandberger of certain fossils (by no means lowest Devonian species) along the northern edges of the Taunus, have substantiated the views originally embraced by Professor Sedgwick and myself. Commencing our inquiry, however, where the order of superposition, aided by paleontology, diffuses a clear light, we find in the Rhenish countries the following ascending series of the Devonian rocks properly so called :—

Lower Devonian or "Spirifer-Sandstein," and Wissenbach Slates, &c. — Slaty schists, with interpolated sandstones and quartzose rocks, with a rare trace of impure limestone, rise up in numerous folds from beneath all the adjacent strata in the gorge of the Rhine between Coblentz and Caub. This is the "Aeltere Rheinische Grauwacke" of F. Roemer, or the "Spirifer-Sandstein" of Sandberger. This mass being on the whole very schistose, and having a very pronounced transverse slaty cleavage, the true undulations of the beds can be recognized by practical geologists only; still the distinction between cleavage and stratification is clearly to be seen.

These rocks contain many remarkable fossils; among which may be noticed the large and broad-winged Spirifers—S. macropterus and S. speciosus, Terebratula Archiaci, many species of Pterinea, some Orthides, especially O. circularis, Leptæna plicata, Chonetes semiradiata, Sow. (C. sarcinulata, Schloth.?), Pleurodictyum problematicum, Phacops (Cryphæus) laciniatus, Ph. latifrons, and both smooth and spinose species of Homalonotus,—H. Ahrendi and H. armatus, &c.†

According to the Prussian geologists, the thin band of the Wissenbach slates, with its numerous small pyritized orthoceratites and goniatites (the chief of which are Orthoceras (Bactrites) gracile and Goniatites compressus), overlies the Spirifer Sandstone. In admitting that the fauna of this slaty band is rather peculiar, MM. Sandberger affirm, that it contains from eight to ten species like those of the Spirifer Sandstone; among which are Nucula solenoides, Goldf., Phacops laciniatus, Roem., and P. brevicauda, Sandb. Thus, by means of their imbedded organic remains, a natural union subsists between these two rocks, which, in the Rhine country, constitute the Lower Devonian‡.

* MM. F. Roemer and Fridolin Sandberger agree in this opinion.

† The Homalonotus Herschelii, 'Sil. Syst.,' a fossil formerly sent to me from the Cape of Good Hope by Sir John Herschel, and all the spinose forms of this genus, are now believed to belong to Lower Devonian, and not to Upper Silurian rocks. (M. Sandberger in Neues Jahrb. 1852, p. 581; and Messrs. Sharpe and Salter in Trans. Geol. Soc. 2 ser. vol. vii. p. 204.)

‡ In the Caub slates, which are intercalated in the sandstones of the lower division, the MM. Sandberger have found Phacops laciniatus, with P. latifrons, Homalonotus planus, and some Orthoceratites.

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This Lower Devonian mass—at least, all that portion of it which is characterized by broad-winged Spirifers—was long ago recognized* as extending largely over the Prussian provinces on the left bank of the Rhine, which are watered by the Moselle, the Lieser, and the Ahr. This Spirifer Sandstone, spreading over large tracts east and west of Coblentz, comprises both the Système Coblentzien and Système Ahrien of Dumont; for the very same fossils pervade both these districts, watered by the Rhine and the Ahr, and the distinction attempted to be drawn by the eminent Belgian geologist was founded on mineral distinctions only.

Middle Devonian of the Rhine—(Eifel Limestone and younger Rhenish Grauwacke of Ferd. Roemer,—Lenne Schiefer of von Dechen).—The strata which succeed to the Lower Devonian on the right bank of the Rhine, consist, like the previous beds, of schists and sandstones, but lenticular-shaped masses of limestone prevail at intervals. They there occupy a wide tract which is watered by the rivers Agger, Vohne, and Lenne. The Lenne schists of Dechen, as laid down in the splendid and highly illustrated new geological map of the Rhenish provinces, occupy a broad tract of country, particularly on the right bank of the Rhine. After various undulations, and with many associated bosses of erupted igneous rocks, these strata, which are charged with much iron ore, plunge on the right bank of the Rhine under the great band of limestone which, ranging by Elberfeldt and Schwelm to Iserlohn, and appearing also at Paffrath and Refrath near Cologne, is the well-known equivalent of the chief or upper band of the Eifel limestone. A laborious examination of the country, executed by M. Ferd. Roemer, led, however, to the separation of these strata from the lower division or the "Spirifer-Sandstein," and has shown that they are united with the Stringocephalus or Upper Eifel limestone which covers them. It has, in short, been found, that, whilst they contain few species in common with the underlying rocks, they are laden with fossils of the superior limestone. Hence, the Prussian geologists, von Dechen, F. Roemer, and Girard, have for some time been delineating these strata separately on an exquisitely finished geological map of the Rhenish provinces of Prussia, the result of infinite research, and they apply to these rocks the name of "Agger and Lenne group†." This subdivision is another of the many proofs which patient inquiry has brought forth to demonstrate, that it is not possible to form correct geological groups by appealing to mineral characters and superposition only; for these were the grounds on which the strata in question were closely united by my colleague and myself with the greywacke of Ems and Coblentz.

It is now known that the "Agger and Lenne" group is identical with those more schistose courses on the left bank of the Rhine, which, chiefly underlying the Upper Eifel limestone, are known as the "Calceola-Schiefer." There, they are characterized by the presence of the Calceola sandalina, Cryphæus (or Pleuracanthus) punctatus, Cryphæus stellifer, Spirifer cultrijugatus, S. spe-

* Trans. Geol. Soc. 2 ser. vol. vi. p. 280.

† This beautiful Map, which, when completed, will consist of 30 large sheets, 'Geognost. Karte der Rhein-provinz und Westphalen,' is one of the noblest memorials of the school of Leopold von Buch, the great geological cartographer of the period; and whilst it does infinite honour to the Director of the Survey, my eminent and valued friend, H. von Dechen, and his associates, is a proof of the enlightened encouragement of geological science by the Prussian Government. In the first edition of this work it was stated that a portion of the map had been executed by Dr. Girard, now Professor at Halle.

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ciosus, S. heteroclytus, and many other fossils which are common both in the Eifel country and in some of the limestones of South Devon. In following these formations into Belgium, a similar order of superposition is found to prevail.

Chief Eifel Limestone.—This is the great central calcareous mass which gives to the Devonian rocks their dominant and independent characters; for, whilst the Lower Devonian of the Rhine exhibits, in some of its forms, analogies only to the Upper Silurian type, the limestone to which we have now ascended, and the approach to which is clearly indicated by the fossils in the preceding strata, contains a fauna which is unmistakeably peculiar, and *wholly unlike* that of the Silurian below or the Carboniferous above it. One of the most striking Rhenish types of this rock is the Stringocephalus Burtini, which is mainly characteristic of that which is now considered the uppermost band, as at Paffrath and Refrath on the right bank of the Rhine. The other prevailing fossils are, Uncites gryphus, Davidsonia Verneuilii, Spirifer undiferus and S. lævicosta, Megalodon cucullatus, Lucina proavia, Murchisonia bilineata, and the corals, Cyathophyllum cæspitosum, Favosites polymorphus, Heliolites pyriformis, &c.

Laden with a profusion of corals, crinoids, and other fossils, many of which have been made known through the beautiful works of Goldfuss, it is unnecessary here to dilate further on the numerous organic remains of this rock, very many of which are common, as before said, in Devonshire. It may, however, be stated, that in the Eifel country, as well as in the Harz, *the Coccosteus and other ichthyolites have been detected, which, as in Russia* (see p. 381), *serve to identify the rock as an equivalent of the central member of the Old Red Sandstone of Britain.* Among the organic remains are likewise several types, which connect this band with the subjacent strata of Spirifer Sandstone, such as Phacops latifrons, Bronn, and Cryphæus punctatus, Steininger; with Spirifer speciosus, Schloth., S. cultrijugatus, Roem., &c.*

Upper Devonian of the Rhine—(Clymenia and Goniatite Limestone, von Buch and Münster; Cypridina-Schiefer, Sandb.; Kramenzel-Stein and Flinz with Spirifer-Verneuilii-Schiefer, &c., von Dechen).—Although we observed and noted, that the chief masses of the Devonian limestone in the Rhenish provinces were frequently followed by other courses of impure limestone, my colleague and myself did not propose that separation which has already been adverted to as existing in Devonshire between the lower (or Stringocephalus) limestone of Plymouth and the superior or Clymenia limestone of Petherwin. The researches of the able paleontologists of the Rhine, to whom allusion has already been made, and those of M. de Koninck in Belgium, have, however, led to a separation which more clearly identifies the succession of rocks in these foreign tracts with that in Devonshire. M. Adolf Roemer, for example, divides this upper group into the following ascending series:—1. Receptaculite schists, so called because they are charged with the Receptaculites Neptuni, Defrance; 2. Limestone characterized by Goniatites auris, and other species; 3. Schists with many Goniatites, Clymeniæ, and Cypridinæ; 4. and lastly, Schists con-

* See the comparative table of Adolf Roemer, Geol. Kenntn. Nordw. Harzgebirges; Dunker and von Meyer's Palæontographica, 3 Band, p. 1, 1850; also the memoirs of MM. Sandberger, Verneinerung. Rhein. Schichtensyst. Nassau, 1850; and Frid. Sandberger, Geol. Verhaltn. Nassau (with map). Wiesbaden, 1847, &c. These works of MM. Sandberger are full of accurate detail.

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taining Rhynchonella cuboides and Productus subaculeatus,—beds which are paralleled by that author with the Upper Devonian strata of North Devon. Looking, however, at this Upper Devonian division in a broad point of view, as it generally appears in Germany, it seems to me to be more frequently characterized by the small crustacean Cypridina serrato-striata, than by any other fossil. Where the calcareous courses thin out, and Clymeniæ and Goniatites, or other characteristic shells, are not persistent, still the minute crustacean is almost everywhere present, often ranging through a considerable succession of beds, and giving to them their prevailing zoological character. In each country, however, through which this division ranges, it exhibits some peculiar features, though in most tracts it is chiefly marked by containing Cypridinæ, Clymeniæ, and certain Goniatites. The name, therefore, of "Cypridina-Schiefer," adopted by MM. Sandberger, who have described so many of the organic remains of this remarkable band of rocks, is, I repeat, highly characteristic of it as a whole.

In Nassau, where the upper limestone is, in some places (as near Weilburg), very little removed from the lower or massive Eifel limestone, it has only to be followed a short distance eastwards, to be seen divided from its neighbour by copious strata of the plutonic rock called "Schaalstein," which was formed out of submarine volcanic ejections.

But it is along the northern frontier of Westphalia, where all the Devonian rocks subside conformably beneath the overlying carboniferous deposits, that they assume an importance, which can be well understood only by inspecting the remarkable Prussian map, before spoken of. There, as is well seen in the cuttings of the Bergisch-Mergisch railroad, the group above the Stringocephalus limestone exhibits, first, slaty schists with some thin layers of grey and black limestone containing Goniatites retrorsus; strata which at Nuttlar attain the great thickness of 1000 feet ("Flinz" of von Dechen). These are micaceous sandstones often running into concretionary forms, as seen at the Rauhe Hardt, near Iserlohn. Then appear the reddish schists with Cypridinæ and a nodular limestone, which, from the cavities it weathers into, has been called "Kramenzel-stein," or ant-stone*, the greatest thickness of which is about 200 feet.

It is this nodular Kramenzel-stein, and the associated schists and sandstone, frequently of a reddish colour, which are most charged with Cypridinæ and Clymeniæ, and they give to the upper group its chief character. When most extended, including the schists called "Flinz," the group has the dimensions of upwards of 1300 feet. This Upper Devonian, in the form of "Cypridina-Schiefer" and Clymenien-Kalk, as before explained, is much developed in Saxony and in the adjacent tracts of Thuringia and Franconia. (See the foregoing chapter.) The overlying sandy, calcareous band with the Spirifer Verneuilii† terminates in ascending order the Upper Devonian of the Rhine and Belgium, and is distinguished by a separate colour in the Prussian map‡.

* The cavities are frequently filled with ants' nests; hence this name, given by the workmen.

† Von Dechen and his associates have used the name given by myself in honour of my friend de Verneuil to the Spirifer which abounds in the same stratum in the Boulonnais (see Bull. Soc. Géol. de France, vol. xi. p. 252). It is, however, the Spirifer disjunctus, having been previously so named by Sowerby.

‡ The Prussian geologists have even delineated on their map three divisions in this one group, which in ascending order are: 1. Flinz; 2. Kramenzel-Stein; 3. Verneuilii-Schiefer.

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Devonian Rocks of Belgium.—The oldest rocks in Belgium are those of the Système Ardoisier of Omalius d'Halloy, or Terrain Ardennais of Dumont, so called from the great development of those slaty, quartzose masses, which rise into the lofty and wild hills of the Ardennes*. These rocks, including the local divisions or systems of M. Dumont, called Devillien, Revinnien, and Salmien, and even the Gedinnien, or base of the Terrain Rhénan of that author, are now considered by M. de Koninck to be of Lower Silurian age, seeing that they contain only a few imperfect traces of fossils, none of which are of Upper Silurian characters, and also that these slates and grits are *unconformably* surmounted by the lowest zone of true Devonian rocks.

The triple division of the Devonian rocks of the Rhine, proposed in the first edition of this work, is found by M. de Koninck to be essentially correct and applicable to Belgium as determined both by superposition and organic remains. The lowest beds, consisting of quartzose conglomerates, and exhibiting imperfect casts only of Rhynchonella and Orthis allied to species of the earliest Devonian age, are followed by schists which are laden with those fossils which are common in the lowest fossiliferous rocks visible on the banks of the Rhine and its tributary the Ahr. On this point, M. de Koninck agrees with the Prussian geologists, von Dechen and Ferd. Roemer, and with myself, that the so-called *Systèmes* Coblentzien and Ahrien of Dumont are absolutely one and the same deposit. (See the Table at the end of the chapter.)

Occurring in Brittany and other parts of France, as will presently be shown, these beds are, as before said (p. 294), represented in N. Devon by the sandstone rocks forming the North Foreland and cliffs of Ilfracombe; whilst, judging from some of the fossils, M. de Koninck thinks, with us in England, that they have also their equivalents at Hope's Nose and Meadsfoot near Torquay in Devonshire, and at Looe and Fowey in Cornwall.

The same group of fossils has, indeed, a very wide range, and has been recognized in the Asturias and other parts of Spain, at Constantinople, and at the Cape of Good Hope, if not in Tasmania. This is the zone which is characterized by the broad-winged Spiriferi, Spirifer macropterus, Goldf., and S. cultrijugatus, Roem., and was well termed "Spirifer-Sandstein" by Ferd. Roemer. The other principal fossils are, Orthis resupinata, Sow., O. Sedgwicki, de Vern., Terebratula Archiaci, id., Chonetes sarcinulata, Schloth., Pterinea lineata, Goldf., Grammysia Hamiltonensis, de Vern., Homalonotus armatus, Burm., and Pleurodictyum problematicum, Goldf., &c. M. de Koninck enumerates, in short, 23 species which are common to Belgium and the Rhine, many of them being also known in Devonshire; whilst not one of them has been detected in an Upper Silurian rock in any part of the world.

* In the Prussian geological map these slates are also grouped as Devonian.

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Just as in my own table, the Wissenbach slates are placed by M. de Koninck at the summit of this Lower Devonian division.

The Middle Devonian of Belgium, or calcareous centre of the series, is described by M. de Koninck as consisting of several bands. The inferior strata are quartzose, schistose, and calcareous, with partial conglomerates (Burnot), and exhibit few fossils; next, limestone laden with true Eifel fossils, including Phacops latifrons, Bronn, Brontes flabellifer, Goldf., Spirifer heteroclytus, Defrance, with Stromatopora, Cyathophyllum, and many other corals.

A thin course of limestone with Calceola sandalina succeeds, and a suite of fossils which occur in the Devonshire limestones of Plymouth, Newton Bushel, and Chircombe Bridge, and which are unknown in France and in the Harz. Among these are, Phragmoceras pyriforme, Goldf., Cyrtoceras nodosum, Bronn, Orthoceras nodulosum, Schloth., Capulus priscus, Goldf., Bellerophon tuberculatus, Féruss., Lucina proavia, Goldf., Orthis umbraculum, v. Buch, Spirifer speciosus, Goldf., S. ostiolatus, Schloth., S. curvatus, Schloth., Rhynchonella primipilaris, v. Buch, with two species of Cupressocrinus. This group, according to M. de Koninck, occurs also in China and Australia.

The upper portion of the Middle Devonian consists of the limestone with Stringocephalus Burtini and other well-known fossils, viz. Uncites gryphus, Schloth., Megalodon cucullatus, Goldf., Murchisonia bilineata, Goldf., Macrocheilus arculatus, Goldf., and Sphærocrinus geometricus, Goldf. In placing this bed at the summit of the Central Devonian or Eifelian group, M. de Koninck is in accordance with Ferd. Roemer and the Prussian paleontological authorities. In Brabant, as at Soignies and Ecaussines, it reposes upon the Lower Devonian, and is in every respect the equivalent of the limestones of Paffrath, Refrath, Münster-Eifel, and Villmar, in the Rhenish countries. In Devonshire, M. de Koninck identifies with this band the limestones of Bradley, Babbacombe, and Newton Bushel, and compares it with the Marcellus schists and Hamilton group of North America.

In following the Devonian rocks from the Rhine towards Belgium, it is found that their details differ from those of Westphalia. At Aix-la-Chapelle, where the Belgian type may be said to begin, all the members of the series are much attenuated. We there find a meagre equivalent only of the Lower Devonian; the calcareous representative of the Eifel being but a poor coralline rock, in parts dolomitic, followed only by certain nodular schists charged with the Receptaculites Neptuni, Defrance, and Spirifer disjunctus, Sow., which alone represent the copious masses of Flinz, Kramenzel-stein, &c., of the previously mentioned tracts.

The Upper Devonian of Belgium (part of the Eifelien and part of the Condrusien inférieur, Dumont) consists at its base of calcareous schist

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with nodules, and is specially characterized by its abundance of Clymeniæ, Goniatites, and Favosites; besides which, it contains Receptaculites Neptuni, Defr., Davidsonia Verneuilii, de Kon., Avicula Neptuni, Goldf., Orthis Dumonti, de Vern., Rhynchonella cuboides, Sow., Cardium palmatum, Goldf., and Cypridina serratostriata, Sandb.

This band is paralleled with the beds of Budesheim in the Eifel, with the red limestones and iron-beds of Nassau described by Sedgwick and myself*, with the base of the Petherwin group in Cornwall, as with the strata of Neuilly (Hersult) in France, and the rocks of Elbersreuth and Schubelhammer in Bavaria, illustrated by Count Münster. It is the Genesee slate and Tully limestone of N. America, and is considered to have its representative in the "Domanik-Schiefer" of Keyserling, on the banks of Uchta in the north-eastern extremity of Russia in Europe, whence the fossils range even into Nova Zembla.

The group terminates upwards in a mass of schists of olive and brown colours alternating with calcareous and dolomitic courses; the whole forming the usual borders of the coal-basins of Belgium. This, the highest Devonian group, is characterized by containing Orthis striatula, Schloth., Spirifer disjunctus, Sow. (S. Verneuilii, mihi), S. comprimatus, Schloth., Strophomena Dutertrii, de Vern., Productus subaculeatus, Murch., Acervularia pentagona, Goldf., Favosites polymorphus, Goldf., &c.

This is the upper member of the Petherwin group of English geologists, and is represented in N. Devon by the sandy rocks of Barnstaple, Pilton, Croyde, Baggy Point, &c. It has been traced by de Koninck in Belgium, at Manche, Rhisme (Namur), Huy, Verviers, Chaufontaine, and Philippeville, and is well seen in the Boulonnais, where it is clearly distinguished from the lowest Carboniferous rocks, by which it is conformably surmounted.

Certain fossils of this age have as wide an extension as those of the underlying divisions of the Devonian rocks; since they have been identified by Davidson, de Koninck, Salter, &c., from China† and other parts of Asia, and are abundant in Russia and Siberia.

In terminating this sketch of the Devonian rocks of the Rhenish provinces and Belgium, it may be observed, that, notwithstanding a certain general aspect, even the lowest Devonian, here indicated, is entirely different in species from the Upper Silurian type of any part of Europe; whilst the middle, or typical, Devonian is still

* See Trans. Geol. Soc. Lond., 2 ser., vol. vi. p. 250.

† The celebrated missionary, Mr. W. Lockhart, who has just communicated to the Royal Geographical Society a comprehensive memoir on the great watercourses and on the productions of China, has supplied me with Upper Devonian fossils from the province of Tse-chuen, in the interior of that vast country, which are identical in specific character with Spirifer Verneuilii, S. Archiaci, Productus subaculeatus, and other European forms: coal also abounds in that region.

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more distinct. Neither of these rocks contain, for example, any Silurian species of crustacean or cephalopod; the genera of the central masses are peculiar; and graptolites, which occur from the bottom to the top of the Silurian rocks, are unknown in any Devonian stratum. The Devonian and Upper Silurian are, therefore, infinitely more distinguished from each other, as natural-history groups, than the Lower and Upper Silurian, which, on the contrary, are intimately linked together, as proved in the earlier chapters, by a considerable number of the same *species* of crustaceans, cephalopod and brachiopod shells, corals, and graptolites.

According to de Verneuil, the Lower Devonian of the Rhine is the equivalent of the Oriskany sandstone of the United States, as will be explained in a subsequent chapter. Other analogies have been indicated by means of their fossils, between these Continental deposits and the Marcellus slates and Hamilton group of North America. But, for the present, let us simply bear in mind, that, whether we regard the physical order of the masses, or their imbedded remains, the Rhenish and Belgian rocks, which have afforded more than 450 species of fossil animals, are not only really remarkable counterparts to the succession in Devonshire, but, in consequence of the perseverance and activity of their explorers, have already much outnumbered in fossils their British equivalents.

Carboniferous Rocks of the Prussian Rhenish Provinces and Belgium.—The upward succession from the Devonian rocks into the Carboniferous deposits is clear on both banks of the Rhine and in Belgium; and if in the latter country certain lower carboniferous schists are attenuated, this thinning-out of one portion is more than compensated by the presence of noble masses of carboniferous limestone.

The carboniferous limestone of Belgium reposes, however, upon the Devonian schists containing the Spirifer disjunctus (or Verneuilii), the well-known fossil of the Rhenish Prussian tracts and the Boulonnais, without any trace of those lower sandstones which are so largely intercalated in Scotland and Ireland (p. 312 *et seq.*). This carboniferous limestone, and a thin overlying sandstone representing the Millstone grit, form the support of the two great coal-basins of Liége and Hainault. The numerous repetitions and folds of this rock, as distinguished from the lower or Devonian limestone, are admirably displayed in the map and sections of M. Dumont.

During his earlier researches, M. de Koninck was led to believe in the

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existence of two distinct zones of carboniferous limestone, as expressed in the first edition of this work (p. 375); the fossils of the tract near Visé being very different from those of Tournay. He now, however, has come to the conclusion, that both these form one natural mass; since, although their respective fossils differ materially, they are closely united by a number of species common to each district. Illustrating and extending the application of his views, M. de Koninck further suggests, that the fossil species of Visé and Tournay are repeated in like manner in several localities of the British Isles respectively; and he traces the same distinction over the Continent to the Ural Mountains on the east, and across the Atlantic to America on the west.

In making these extensive comparisons, M. de Koninck enumerates 53 species as distinctive of the Visé assemblage, and 57 species as characteristic of Tournay; whilst he cites 40 species which are common to both localities. The latter, or the common forms, belong chiefly to the genera Euomphalus, Pleurotomaria, Bellerophon, Productus, Orthis, Athyris, Rhynchonella, with the trilobite Phillipsia, and palates of the Psammodus and other fishes.

Through the comparisons instituted by this able paleontologist, we learn, that many of the same species were so widely spread out during the Carboniferous era as to extend over the northern hemisphere; being here and there collocated in distinctive assemblages, often at great distances from each other,—those parts of the ocean having been specially suitable to their existence.

The splendid rocks of this formation, which the traveller admires as he passes along the railroad from Namur to Liége, gradually thin out as they range towards the Rhine. They make, in short, their last appearance as a solid limestone at Cromford near Ratingen, on the right bank of the Rhine; for in extending thence to the east and north they become almost non-calcareous. Instead of two or more massive divisions, they dwindle into one or two thin, flat beds of black limestone, very similar to the black culm-stone of Devonshire, which is in that district the feeble representative of the great Carboniferous or Mountain Limestone of other parts of England. Like the Devonshire rocks, the Westphalian strata are characterized by the Posidonomya Becheri, which occurs in Belgium, even where the calcareous matter is entirely absent, as well as in the schists of Herborn and other places, distinctly marking the *centre* of the Lower Carboniferous rocks.

In the German Rhenish provinces, the lower member, or the schists below the limestone (Lower Sandstone shale), is usually very siliceous, and is, in that tract, the "Kiesel-Schiefer" of the Prussian geologists, which occasionally expands into a deposit of considerable dimensions. The limestone which reposes on these schists and sandstones is again surmounted by a copious succession of sandstone, mineralogically not very unlike many of the inferior divisions of the so-called "grauwacke," and which was also formerly known under the name of "Flötz-lehrer Sandstein." Professor Sedgwick and myself showed, that, while

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the Posidonomya beds represented the "culm," or true Carboniferous limestone, this "Flötz-lehrer Sandstein" or "jüngste grauwacke" was simply the equivalent of our British millstone grit, and that, as in England, it lay immediately beneath the most productive coal-fields.

This identification was, in truth, one of the most satisfactory assurances, that a knowledge of organic remains, combined with a clear view of the order of superposition, had led us to a correct inference in placing as a member of the carboniferous deposits strata which had been previously connected with much more ancient rocks.

Having thus briefly indicated the character of the rocks which form the immediate support of the upper or productive carboniferous strata of Westphalia and Belgium, it is not my object to attempt any detailed description of the coal-measures properly so called. In Westphalia the coal beds plunge under the cretaceous rocks upon the east; and in Belgium (as, for example, at Liége) they are at once surmounted by tertiary deposits. (See Dumont's Maps.)

Whilst the Devonian rocks of the Rhine, unlike those of Saalfeld (p. 408), have afforded few traces of land plants, it is important to observe, that specially in this Lower Carboniferous group nearly all the so-called transition and "grauwacke" fossil vegetables described by various German authors have been collected. Seeing that this series, in the Rhenish provinces, is so very analogous to that of Britain, geologists will indeed be interested in comparing the plants described by Göppert, Unger, and others with the rich flora of the same age found in Northumberland*, Scotland, and parts of Ireland.

Although not adopted by the Prussian geologists in the great map of the Rhine provinces, it is right to mention the opinion of M. R. Ludwig†, that the quartzites above Nauheim, which seem to be an eastern prolongation of the Taunus mountains, and repose unconformably upon certain Devonian rocks, are—judging from their mode of bedding, mineral character, and above all from the large land plants they contain—equivalents of one of the oldest members of the carboniferous series. On this point I cannot pretend to express a decided opinion without a more elaborate examination than I have yet given to the tract. M. von Dechen does not adopt this view.

Inversions.—Inadequate as the preceding brief sketch may be in conveying a just idea of the nature and contents of the older deposits of this interesting region, it would be still more imperfect if a reference, however cursory, were not made to the phenomenon of the inversion of some of its stratified rocks. Adopting the explanation of M. Dumont,

* See remarks, by Mr. G. Tate, on the fossil flora of the Coal formation, in the 'Natural History of the Eastern Borders,' by Dr. Johnston, 1853.

† See 'Rheinische Schiefer-Gebirge,' with a map. Jahrbuche der Vereins für Naturkunde in Herzogthum Nassau. Wiesbaden, 1853.

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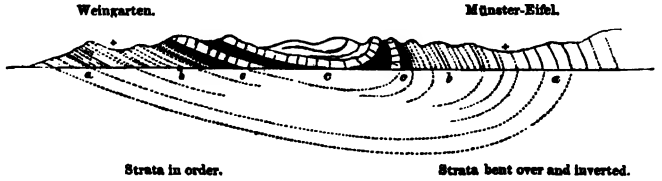
of such reversals of the normal order in Belgium, Professor Sedgwick and myself applied it to account for the position of certain masses of the Eifel country. We pointed out how, near Münster-Eifel, the overturning of the beds had been produced by movements which acted throughout masses of sediment several thousand feet in thickness. The phenomenon is illustrated by this diagram†.

INVERSION IN THE EIFEL EXPLAINED.



c. Eifel limestone and shale.
a, *b*. Shelly Devonian greywacke.

In this case, whether by following the strata upon their strike, or by making a short traverse across them, as in the preceding section, the true order was soon detected.

Again, on the northern or outer frontier of the Devonian rocks of Westphalia, where the order is very regular, all such strata being seen to plunge under the Carboniferous beds, as before explained, the attention of the observer is roused when, exploring north-westwards to Brilon, he finds a large tract of country (much penetrated by very ancient igneous rocks) which, extending towards Berleburg, exhibits everywhere the older beds overlying the younger. This phenomenon, long ago known to the Prussian geologists von Dechen and Erbreich, is expressed in this woodcut, taken from part of a larger section published by my colleague and myself in the Geological Transactions‡.

INVERTED STRATA SOUTH OF BRILON.

c. Lower Carboniferous (Kiesel-Schiefer and Posidonomyen-Schiefer).
b. Upper Devonian schist, lime, and iron ore } Devonian.
a. Slaty Devonian rocks ..... }
* Bands of igneous rocks.

The reader will see that the lower carboniferous rocks (*c*), consisting of the "Kiesel-" or "Posidonomyen-Schiefer" (Table, p. 432), which in their true positions are overlying, here dip under the upper or calcareous Devonian group, *b*; whilst the last have been carried under still

† From Trans. Geol. Soc. vol. vi. p. 277.

‡ See Sedgwick and Murchison, Trans. Geol. Soc. Lond. vol. vi. p. 239. The woodcut in the Geological Transactions shows the coal strata to the north covered by cretaceous rocks.

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older members of that series (*a*), or the slaty "grauwacke" of this region. Nay more, he perceives that igneous rocks, or porphyries, greenstones, &c., formed in part successively on the bottom of the same seas, in which the Devonian strata (*b*) were accumulated, have also been overthrown *en masse* with all the other rocks. It follows, therefore, that the regular order in which these formations are traceable along so wide an adjacent region is here completely deranged, and that all the rocks are inverted, the older being incumbent on the younger! Now, this very same phenomenon of the overturning of huge masses of the solid crust of the earth has not had its limit in the Rhenish provinces, but has extended into Belgium, where the same strata, as described by M. Dumont, are affected along a band having precisely the same strike as those great folds in Westphalia and the Eifel*. They are, therefore, to be considered as great, parallel, wave-like undulations, similar to those which have been ably explained by the Professors Rogers of the United States.

In looking back to p. 161, we see, indeed, that in Cornwall, this great European inversion has proceeded much further to the west, and that masses, of an antiquity unknown in the Rhenish provinces and Belgium (*i.e.* the Lower Silurian), there overlie Devonian strata. In that example, both the rocks being fossiliferous, no doubt as to the intensity of the overthrow can exist.

In the earlier part of this chapter it is also shown, that, in one district of Thuringia, certain plant beds, which belong to the Lower Carboniferous division, plunge under Upper Devonian beds charged with Cypridinæ and Clymeniæ, and that near Ober Steinach, in Meiningen, these Devonian strata are likewise apparently surmounted by true Lower Silurian!

If a young geologist had detected, for the first time, such abnormal relations in a country like the Eifel, where, besides igneous eruptions of remote periods similar to those in the last diagram, the strata have been pierced by volcanos which have certainly been in activity under the atmosphere, he might suppose, that the latter, with their craters and coulées, must have been associated with an influence analogous to that which produced the inversions. But a cursory examination dispels the hypothesis; for we see that these sub-aërial volcanos, with their scoriæ, pumice, lava, and ashes, are nothing more than mere superficial pustules, which, in bursting forth, spent their energies for ever, and produced no sort of alteration in the position or nature of the rock-masses. They merely vomited their contents into depressions already prepared to receive them; thus showing us that when they appeared the present system of hills and valleys had been completed.

* See the very remarkable geological map of all the volcanic tracts in the Rhenish Provinces, by M. v. Oeynhausen.

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Infinitely more intense, therefore, must have been that much deeper-seated agency, which, giving rise to such internal writhings of nature, inverted thousands of feet of strata over vast areas, and bending them in some tracts like reams of paper, placed them in others over deposits formed at immeasurably subsequent periods. But, striking as are the above-mentioned features of inversion, still grander examples will be adverted to in the sequel.

After all, such phenomena of inversion are only local exceptions, as respects the surface of the globe, on which, fortunately, the original impress of order is visible over very large regions. In reverting then to such order, I annex the following Table of the natural divisions of the Devonian and Carboniferous rocks of the Continent as compared with their equivalents in the British Isles, the whole surmounted by the Permian rocks described in the thirteenth chapter. In this Table, the student sees at one glance the whole of the Upper Paleozoic succession; the Silurian strata constituting the lower part of the Paleozoic system. It is substituted for one on a more limited scale given in the first edition of this work, relating to the tracts described in this chapter only, and which was chiefly prepared to show both the triple subdivision of the Devonian rocks, and also that not one of those groups, as based upon the distribution of former life, was in unison with the lithological groups and systems of the late M. Dumont*. That eminent geologist, who had so admirably reduced to order the complicated and often inverted strata of his native country around Liége, undervaluing the weight of fossil evidence, proposed a classification based solely upon the mineral character of each succeeding mass. Such division, being found to be inconsistent with the great principle of modern geology—strata identified by their organic remains, is no longer adverted to, and the Table now laid before the reader, though susceptible of much improvement, is, it is hoped, established on a truthful basis, and applicable to wide areas of the earth's surface.

* See 'Siluria,' 1st ed. p. 381.

[TABLE

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TABLE OF THE UPPER PALEOZOIC ROCKS IN EUROPE, FROM THE SUMMIT OF THE SILURIAN TO THE PERMIAN INCLUSIVE.

Groups.	Divisions.	Subdivisions.	Characteristic Fossils.	British Localities.	Foreign Localities.	Remarks.
PERMIAN.	Upper.	Marl Sand and Conglomerate (of Perm). (Sand-schiefer or Lower Bunter, Germany.)	VERTEBRATA.—Rhopalodon Mantellii, Fisch., R. Murchisoni, id., R. Wangenheimi. PLANTS.—Calamites arenarius, Neuropteris salicifolia, Odontopteris Strogonovii, O. Permiensis, Pecopteris Gœpperti, Sphenopteris lobata, S. erosa, Nœggerathia, Lepidodendron elongatum, &c.	Red sandstone and marl west of Doncaster. In England a partial capping only of the Magnesian Limestone.	*Russia*.—Governments of Perm, Orenburg, and Kazan. *Germany*.—Flanks of the Thüringerwald and of the Harz; environs of Gera; Altmorschen, Hesse.	See 'Russia in Europe,' for places where conglomerates, &c., with copper, Rhopalodon, and plants *overlie* and *interlace* with Zechstein.
	Middle.	Zechstein. (Magnesian Limestone of England.)	VERTEBRATA.—Zygosaurus lucius, Platysomus striatus, Palæoniscus. INVERTEBRATA.—Terebratula elongata, T. Geinitziana, Spirifer alatus, Camarophoria Schlotheimii, Productus horridus, Strophalosia Goldfussii, Athyris pectinifera, Pecten pusillus, Monotis speluncaria, Bakewellia antiqua, Byssoarca striata, Schizodus dubius, Turbo helicinus, Pleurotomaria antrina, Nautilus Friesiebeni, Fenestella retiformis, Phyllopora Ehrenbergii, Cidaris Verneuiliana.	Coast cliffs from Tynemouth to Hartlepool. Clackaheugh, Eldon, Thickley, Ferry Hill, Humbleton Hill, Durham; Masham, Roach Abbey, Bramham Moor, Ferrybridge to Tadcaster, Knaresborough, Yorks; Bolsover Castle and Moor, Cuswell Crags, and Steetly, Notts.	*Russia*.—Pinega, Ust Vaga to Archangel, Kirilof, Kasan to Perm, Sergiefsk, Rivers Kidash and Dioma; abounds in Perm and Orenburg. *Germany*.—Flanks of Thüringerwald and Harz; East flank of Westerwald from Saalfeld to Gera; Silesia, Löwenburg.	In Russia, limestones containing the shells of Germany and England alternate with copper sands, marls, saliferous springs, rock-salt, &c. The plants of these bands in Russia are those of the German Roth-liegende.
		Kupfer-schiefer. (Marl Slate.)	VERTEBRATA.—Protorosaurus Speneri and Parasaurus Geinitzii, Palæoniscus elegans, Platysomus striatus, Pygopterus mandibularis. PLANTS.—Caulerpa selaginoides, Neuropteris Huttoniana.	Thickley, Ferry Hill, Durham; Escarpment of Magnesian Limestone from Bramham Moor to Nottingham.	*Germany*.—Mansfeld to Eisleben, Glücksbrunn, &c.; Thüringerwald.	
	Lower.	Lower Red Sandstone (England). (Weiss- and Roth-liegende.)	VERTEBRATA.—Palæoniscus Vratislaviensis, Acanthodes gracilis, Pleuracanthus Decheni, &c. PLANTS.—Psaronius helmintholithus, Araucarites Saxonicus, Guglielmites Permianus, Walchia filiciformis, Calamites gigas, Neuropteris conferta, Odontopteris obtusiloba, Pecopteris Gœpperti, Adiantites prisca, Gleichenites Gœpperti, Sphenopteris erosa, S. lobata.	Clackaheugh, Durham; Plumpton Rocks, Knaresborough, and Pontefract, Yorks; Astley, Lancashire; Corncockle Muir, Dumfries; Wolverhampton to Coalbrook Dale. S. of Shrewsbury, W. of Birmingham, and around the Dudley coal-field.	*Russia*.—Governments of Orenburg and Kazan. *Germany*.—Lower Silesia and N.E. Bohemia, Braunau to Glatz (with limestones); Eisenach and N. Thüringerwald, flanks of Harz, Mansfeld, &c., Zwickau, Oschatz, Dresden.	In Russia, grits with plants (Tchistopol). In Germany, vast conglomerates and red sandstones with the same plants as those of the Middle and Upper bands in Russia.
CARBONIFEROUS.	Upper.	Upper Coal-measures. (Stein-kohl. Houillers.)	VERTEBRATA.—Archegosaurus Decheni, Palæoniscus Egertoni, Gyracanthus formosus, Pleuracanthus (Diplodus), Amblypterus, &c. INVERTEBRATA: freshwater?—Anthracosia acuta, A. aquilina, A. robusta, A. subconstricta. INVERTEBRATA: in marine bands.—Aviculopecten papyraceus, Goniatites Listeri, Myalina, Productus scabriculus, Conularia quadrisulcata, Nautilus elitellarius, Spirorbis carbonarius (attached to plants), Pygocephalus Cooperi, Limulus trilobitoides, L. anthrax. PLANTS.—Sigillaria reniformis, S. tessellata, with Stigmaria, Calamites Suckovii, Lepidodendron Sternbergii, L. elegans, Pecopteris lonchitica, P. oreopteridis, Neuropteris Loshii, Cyclopteris, Sphenopteris latifolia.	South Welsh coal-field and Forest of Dean; Staffordshire, Lancashire, Derbyshire, Yorkshire, Durham, Newcastle, and Whitehaven.	*Germany*.—Lower and Upper Silesia and adjacent tracts of Poland; W. of Dresden; Saarbrück, Dortmund, and Westphalian coal-fields. *Belgium*.—Liége and Hainault. *France*.—Mons, Valenciennes, St. Etienne.	Unknown in Russia. The great upper coal-fields set on in Poland and Silesia, and thence to the west reoccur at the various places cited.
	Lower.	Millstone Grit. (Flötz-lehrer Sandstein.)	INVERTEBRATA.—Productus scabriculus, P. Martini, P. concinnus, Aviculopecten aremosus, A. stellaris, A. papyraceus, Goniatites reticulatus, G. spiralis, Fenestella, 2 or 3 species, Lingula parallela. PLANTS.—Lepidodendron elegans, Stigmaria, Calamites.	Edge of the South Welsh coal-basin; Derbyshire, Penine Chain of England; West and North Ridings, Yorkshire; Culm-trough of N. Devon; part of the Scotch coal-fields? Kilkenny, Clare, and other parts of Ireland.	*Russia*.—West flank of the Ural, Donets coal-field. *Germany*.—Harz and Rhenish provinces of Prussia, edges of coal-fields of Dortmund and Saarbrück. *Belgium*.—Chokier, Ampain, pits near Mons.	The Culm of Devonshire is supposed to be of this age. Some coal beds occur in Yorkshire.
			VERTEBRATA.—Archegosaurus, Parabatrachus Colei, Ctenacanthus major, Orodus ramosus, Psammodus porosus, Cochliodus magnus, C. contortus, Helodus turgidus, H. lævissimus, Pœcilodus transversus, Cladodus, &c.	*England*.—Margin of the South Welsh coal-basin; Derbyshire, Flintshire, Penine Chain, West and North Ridings of Yorkshire, Northumberland.	*Russia*.—Valdai Hills, Moscow, Tula, Kaluga, Donets coal-field, banks of the Volga below Kasan, Archangel, flanks of Ural Mountains, W. of Cracow.	

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DEVONIAN, or OLD RED. — MID CARBON	Carboniferous or Mountain Limestone. (Berg-kalk, Calcaire Carbonifère, with Kiesel-schiefer.)	INVERTEBRATA.—Spirifer striatus, S. lineatus, S. glaber, Terebratula sacculus, Orthis resupinata, Pleurorhynchus aliformis, Euomphalus pentangulatus, Bellerophon apertus, B. cornu-arietis, &c., Orthoceras lateral, O. giganteum, Nautilus cariniferus, Phillipsia Eichwaldi, P. Brongniarti, Griffithides globiceps, Brachymetopus Ouralicus, Lithostrotion junceum, L. striatum, Lonsdaleia floriformis, Melocrinus, Platycrinus, Poteriocrinus, Rhodocrinus, Actinocrinus. PLANTS.—Chiefly the same as those of the Upper Coal.	*Scotland.*—Berwickshire, Scotch coal-fields of Haddington, Edinburgh, Linlithgow, Fife, Lanark, &c. *Ireland.*—Abounds from Fermanagh and Tyrone in the north through the central counties to Cork in the south.	*Germany.*—Hof, Bavaria; Grund, Harz; Ratingen, Westphalia; Hainichen and Ebersdorf, Saxony. *Belgium.*—Visé, Tournay, Namur, Theux, Dinant, Soignies. *France.*—Sablé, Juigné, Bazonge, Fercé, &c. *Spain.*—Picos de Europa, Asturias.	The chief coal-fields of Scotland are subordinate to the limestone of this division. In Saxony M. Geinitz distinguishes the plants from those of the Upper Coal.
	Lower Limestone Shale, Carboniferous Slate, and Yellow Sandstone, Ireland. Calciferous Grit, Scotland.	VERTEBRATA.—Palæoniscus Robisoni, Cladodus striatus, Holoptychius Hibberti, Psammodus turgidus, Platysomus declivis. INVERTEBRATA.—Chonetes Hardrensis, Productus Humboldtianus, Spirifer Mosquensis, S. attenuatus, S. cuspidatus, S. laminosus, Productus semireticulatus, Streptorhynchus crenistria, Nucula tumida, N. attenuata, Modiola Macadami, Rhynchonella pleurodon, Griffithides mucronatus, Eurypterus Scouleri, Gampsonyx, &c. PLANTS.—Sphenopteris affinis, Cyclopteris reniformis, Carpolithes sulcatus, Stigmaria, Lepidodendron, Ulodendron, Calamites, Pinites, and other Coniferæ.	*England.*—Margin of the South Welsh coal-basin, Milford Haven; Derbyshire, Yorkshire, &c. *Scotland.*—Berwickshire, Haddingtonshire, Fifeshire, Edinburgh, lowest coal of Scotland, and freestone of Edinburgh (Craigleith). *Ireland.*—The Hook, Wexford; Ardmore, Waterford; Youghal, Cove of Cork, Mayo.	*Germany.*—Herborn, Arnsberg, and Asbeck, parts of Nassau, the Harz. *Belgium.*—N. of Soignies and Ecaussines.	Less important in South Wales, these lower strata expand much in Yorkshire and Northumberland, and in Berwickshire and other parts of Scotland contain coal. In the south and south-west of Ireland, of great thickness.
	Yellow and Red Sandstone. Petherwin and Barnstaple group. (Cypridinen-schiefer and Clymenien-kalk.) (Flinz, Kramenzel-stein, &c.)	VERTEBRATA.—Telerpeton Elginense, Holoptychius Flemingi, Dendrodus, Pterichthys minor, Onchus, Glyptopomus minor. INVERTEBRATA.—Cucullæa Hardingii, C. trapezium, Avicula Danmoniensis, Spirifer disjunctus, S. Murchisonianus, Athyris concentrica, Strophalosia (Productus) subaculeata, S. caperata, Spirifer Urii, Davidsonia (3 species), Cardium palmatum, Aviculopecten transversus, Clymenia linearis, C. lævigata, Goniatites subsulcatus, Phacops granulatus, P. latifrons, Cypridina serratostriata. PLANTS.—Knorria (or Aspidaria) dichotoma, Sphenopteris Hibernica, Lepidodendron.	*England.*—South Welsh coal-basin and Pembrokeshire; Barnstaple, Baggy Point, Pilton, N. Devon; Petherwin, Tintagel, Cornwall. *Scotland.*—Hoy Head, Orkney; Dunnet Head, Caithness; Tarbet Ness, Ross; Dura Den, Fife; Haddington. *Ireland.*—Knocktopher, Kilkenny, Glanmire, Coomhoola, Cork; Sibyl Head and Brandon Head, Kerry.	*Russia.*—Prussino (St. Petersburg), Valdai Hills, Domanik of the Petschora, Andoma, &c., Petschora-Land. *Germany.*—Sanlfeld, Schuhelhammer, Elbersreuth, Franconia; Weilburg, Dillenburg, Nassau, Nuttlar, Budesheim, Iserlohn (Westphalia). *Belgium.*—Beaumont, Philippeville, Marienbourg. *France.*—Boulonnais, Neffies.	The intermixture in Russia of the marine shells of Devon and the Boulonnais with the same species of fish as in the central and upper members of the Old Red of Scotland and Hereford, distinctly identify the two deposits, as in this Table, and prove the Scottish ichthyolites to be marine. (The Cocconsteus also occurs in the Eifel.) Calceola sandalina, in Britain as in Germany, lies beneath the chief limestone.
	Caithness Flags. Middle Cornstones. Plymouth, Liskeard, and Ilfracombe group. (Eifel group, with Calceoleu-schiefer.)	VERTEBRATA.—Coccosteus, Asterolepis (Pterichthys?, Diplopterus, Dipterus, Glyptolepis, Osteolepis, Holoptychius nobilissimus. INVERTEBRATA.—Calceola sandalina, Stringocephalus Burtini, Uncites gryphus, Spirifer speciosus, Atrypa desquamata, Megalodon cucullatus, Murchisonia bilineata, Cyrtoceras nodosum, C. ornatum, Bronteus flabellifer, Phacops latifrons, Harpes macrocephalus, Helicites porosa, Acervularia pentagona, Cupressocrinus, Sphærocrinus geometricus. PLANTS.—Stems and roots of Coniferous trees. Lepidodendron nothum?, Lycopodites Milleri. Ferns, very rare.	*England.*—Herefordshire and parts of Shropshire (with fishes); S. Devon, Ogwell, Plymouth, Newton Bushel, Torquay, Babbacombe, &c. (with shells). *Scotland.*—Dunbeath and Latheron, to Thurso, Caithness; Kirkwall, Orkney; Findhorn River, Elgin. *Ireland.*—Dingle.	*Russia.*—Livonia, Dörpat. *Germany.*—The Eifel, Münster-Eifel, Daun, Paffrath, Refrath, Agger and Lenne Rivers. *Belgium.*—Poudingue de Burat, Marche, Givet, Philippeville, Visé and Soignies under the carb. limest.; Couvin and Chimay. *France.*—Nehou?, Normandy.	
	Lower Flags and Cornstones (of Old Red). Torbay and Linton group (of Devon). (Wissenbach-schiefer, Spirifer-Sandstein, Coblentz group, and Aeltere Grauwacke.)	VERTEBRATA.—Cephalaspis Lyellii, C. Salweyi, Pteraspis Lloydii, P. rostratus, Onchus. INVERTEBRATA.—Leptæna plicata, Sow. (Orthis Murchisoni, de Vern.), Strophomena explanata, Orthis circularis, Chonetes semiradiata, Spirifer macropterus, S. lævicosta, S. aperturatus, Athyris phaltena, Grammysia Hamiltonensis, Pterinea lineata, Bactrites gracilis, Homalonotus armatus, Phacops laciniatus, Tentaculites annulatus, Ctenocrinus, Pleurodictyum problematicum. PLANTS.—Fragments of linear plants only yet discovered.	*England.*—Silurian frontier; Ludlow, &c.; N. Foreland and Linton, N. Devon; Torquay, S. Devon; Looe, Fowey, Cornwall. *Scotland.*—Carmylie and Glammis, Forfar; Lower conglomerate and sandstone of Ross and N.E. Highlands. *Ireland.*—Glengariff grits; Upper Lakes, Killarney; Valentia; Dingle, no fossils.	*Germany.*—Banks of the Rhine from Bingen to Bonn; banks of the Ahr and Moselle; Rammelsberg, Harz, &c.; Gedoumont. *Belgium.*—Bastogne, Neufchateau, Couvin, Houffalize, &c. *France.*—Nehou; Brulon; Brittany. *Spain.*—Asturias. (S. Africa; Constantinople; Tasmania.)	This zone graduates downwards into the Upper Silurian of Shropshire and Herefordshire; it is omitted in Russia, but is well represented in the Rhenish Prov., France, and Spain. (Terrain Rhénan and Systèmes Ahrien et Coblentzien, Dumont.)
TOP OF SILURIAN. — TILESTONES.	Tilestones, or passage from Upper Silurian into Lower Devonian.	VERTEBRATA.—Plectrodus mirabilis, Onchus Murchisoni, &c.; Pteraspis Banksii and P. truncatus, Auchenaspis Salteri, Cephalaspis ornatus and C. Murchisoni. INVERTEBRATA.—Lingula cornea, Pterygotus, Eurypterus. PLANTS.—Lycopodiaceous seeds and stems, *very rare*.	*England.*—Ludlow, Downton, Onibury, Kington, near Bewdley, &c. *Scotland.*—Arbroath and Balruddery. *Ireland.* (Dunmore Head, Doonquin, and Mt. Eagle, Dingle?, without fossils.)	*Russia.*—Island of Oesel?	This transition-band (Uppermost Silurian, *mihi*) has not yet been found in Germany, France, or Spain.

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CHAPTER XVII.

SILURIAN AND OVERLYING PALEOZOIC ROCKS OF FRANCE, SPAIN, PORTUGAL, AND SARDINIA.

ALTHOUGH the paleozoic rocks, often, however, in a metamorphic state, occupy considerable areas in France, it is not possible, on this occasion, to offer more than a slight sketch of their features even in those tracts where they are clearly exhibited. They are largely developed in Brittany, and the authors of that great work, the geological map of France*, there divide them into two principal masses. The inferior of these is composed of glossy schists (schistes satinés luisans) of great thickness, in which a few thin courses of grit and shaly limestone occur. In their mineral aspect, *and in their entire want of fossils*, these strata remind the geologist of the rocks which underlie the lowest fossiliferous deposits of Bohemia, and they may not unaptly be compared with some of the crystalline and subcrystalline rocks of Anglesea and the Longmynd, or hardest bottom rocks of the Welsh and English series. Their mean direction in Brittany is, like that of the Longmynd in Shropshire, from east 20° north, to west 20° south, and they were termed Cambrian by E. de Beaumont and Dufrénoy.

Under the name of Silurian, these eminent authors include a thick and complex series of fossiliferous strata, which they have again divided into two groups. The lowest of these they thus arrange:—1st, conglomerates and siliceous sandstones; 2nd, bluish schists, which at Angers, Poligny, &c., furnish good slates, and correspond by their fossils to the Llandeilo formation of Britain; Trinuclei and Ogygiæ, with Illænus giganteus, &c., being abundant. So far, the succession in Brittany, as dependent on organic remains, is in unison with that of Britain; but the chief portion of the next division, consisting of compact limestones and schists, has been abstracted by de Verneuil from the Silurian, and shown to belong to the Devonian system. In this way, the order in Brittany

* MM. Elie de Beaumont and Dufrénoy.

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is analogous to that of Cornwall and many parts of Germany, in which tracts, as already shown, there is an equally sudden succession from Lower Silurian to Devonian.

The second group adopted by the authors of the geological map of France, is made up, first, of siliceous conglomerates, coarse grits, and argillaceous schists, which old geologists would term "greywacke," then of beds with coal, and, lastly, of a limestone specially characterized by the presence of Amplexus and Productus. Now, d'Archiac and de Verneuil have demonstrated that this highest group is neither Silurian nor Devonian, but a true member of the Carboniferous rocks. It is, in fact, identical, in its fossils, with the carboniferous limestone of many regions.

All these fossiliferous deposits, whether Lower Silurian, Devonian, or Lower Carboniferous, are conformably arranged, whatever may be the inclination of the beds; and striking from east 15° south, to west 15° north, they overlap transgressively the older unfossiliferous rocks on which they repose. It was the accordance in their direction and inclination which naturally led Elie de Beaumont and Dufrénoy to include, in the first instance, all these fossiliferous deposits in one period. But, in the interval which has elapsed since that classification was proposed, Brittany has been examined by many geologists, including Frappoli, de Fourcy, Durocher, Blavier, Rouault, as well as by de Verneuil and d'Archiac, all of whom agree in adopting the order and nomenclature here announced. The eastern limits of the province, towards the Departments of La Mayenne and La Sarthe, have indeed been studied in the greatest detail by M. Triger, to whom the execution of the geological map of the last-mentioned district was confided. The collection of fossils made in the paleozoic rocks around Cherbourg by my old and indefatigable correspondent, the late M. de Gerville, has also contributed essentially to clear away the difficulties attending a right classification; and lastly, the Geological Society of France (during its meeting at Le Mans, 1850), under the leadership of M. Triger, made an admirable section across the older rocks to the north of Angers, the *résumé* of which was published by de Verneuil and de Lorière.

The following diagram, reduced from their publication, exhibits the principal geological features of the country between Sillé le Guillaume

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SECTION FROM SILLÉ LE GUILLAUME TO SABLÉ. (Dép. Sarthe.)
(From Bull. Soc. Géol. Fr. vol. vii. p. 794. pl. 11. f. 1.)

Carboniferous. { 16. Anthracitic schists, &c. &c. Poillé, Fercé, &c. 15. Carboniferous limestone, with Productus giga, Chonetes comoides, &c. 14. Sandstone, schist, and anthracite, worked at Sablé;—base of the Carboniferous group.

Devonian. { 13. Schists and limestones with Devonian fossils. 12. Quartzose whitish sandstone with Dalmannia calliteles, Homalonotus Gervillei, and other Devonian fossils.

Lower Silurian. { 11. Schists or Ampelite shale, with Cardiola interrupta, Orthoceras pelagicum, Trilobites, and Graptolites, showing a trace of the Upper Silurian base. 10. Ferriferous grit and sandstone (with Cheirurus Tourneminii) like that of May in Normandy. 9. Sandstone and schist with several courses of Ampelite charged with Graptolites. 8. Conglomerate of white quartz pebbles, with some Bilobites and Graptolites. 7. Roofing slates of Parennes with Calymene Tristani. 6. Clay-slate, &c. 5. Thin band of conglomerate in a matrix of talc schist. 4. Magnesian limestone, passing into true dolomite. 3. Argillaceous schist or clay-slate. 2. Siliceous limestone, slightly magnesian, without fossils, and intercalated in schists. 1. Whitish felspathic grit or arkose (bottom rock of the section).

and Sablé, a distance of about twenty-five English miles, and clearly developes a succession of the paleozoic formations, from the Lower Silurian to the Carboniferous rocks inclusive.

In this section, the lowest stratum is a white sandstone (1) resting on a porphyry with large red and white crystals. The still more ancient crystalline and glossy schists of Brittany are here wanting, whilst the lowest visible beds (1 to 6), in which some limestone appears, have not yet afforded any fossils to serve as equivalents for those of the lower zone of Bohemia and Scandinavia, or the Lingula flags of Britain.

The great schistose and slaty mass which follows (Ardoises de Parennes, or 7 of the diagram) forms the inferior limit of Silurian life, as known in France. From its wide extension and its fossils, this formation (Angers slates) merits great attention; for it is doubtless, as M. de Verneuil states, the representative of the Llandeilo rocks of Britain, of the second zone of M. Barrande in Bohemia, and of the Orthoceratite limestones of Scandinavia, Russia, and North America. It is, in fact, the dominant member of the rocks termed Lower Silurian by all the authors who have described them in those countries.

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The slaty masses of Brittany are characterized, like their equivalents elsewhere, by a profusion of trilobites. Unfortunately these crustaceans are, for the most part, much flattened and distorted; but the following species have, notwithstanding, been recognized; some of them having been long ago figured by Guettard and Brongniart*:—

Calymene Tristani, Brong.; C. Arago, Rouault; C. Verneuili, Rouault; Asaphus Guettardi, Brong.; Ogygia Desmaresti, Brong.; Illænus giganteus, Burm. (the last two are gigantic species); Ill. Beaumonti, Rouault; Acidaspis Buchii, Barr.; Phacops (Dalmannia) socialis, Barr.; P. Dujardini, Rouault; Placoparia Tournemini, Rouault; Cheirurus claviger, Beyr.; Lichas Heberti, Rouault; Trinucleus Pongerardi, Rouault†, &c.

Mollusks are scarcer than trilobites; the well-known British species, Bellerophon bilobatus (Sil. Syst.), is, however, not unfrequent. But, as a rule, few of the species of crustacea or of shells are the same as those of Britain, while many are identical with the fossils of this age in Spain and Bohemia.

These Lower Silurian schists, in which graptolites also occur, traverse an extensive tract, as may be seen by referring to the geological map of France, and crop out near the harbour of Brest in the Bay of Crozon, where de Verneuil has detected in them the Calymene Tristani. The deposit affords the best roofing-slates at Angers, where the quarries are 300 to 400 feet deep. There the lines of original deposit and the laminæ of cleavage coincide. In fact, the remains of the included trilobites occur along the division by which the highly inclined slates are cleaved; a phenomenon rarely observed in Britain, where the cleavage is usually oblique to the bedding. (See p. 32.)

The peninsula of the Cotentin also contains these trilobite schists, near Siouville, and in that tract the late M. de Gerville collected their fossils, including Calymene Tristani.

That species has recently been found in the hill of La Roule near Cherbourg, in slates which underlie the hard siliceous sandstones so largely employed in the construction of the great breakwater of that port;—rocks which, according to de Verneuil, are the exact equivalents, in age as well as in lithological structure, of the Caradoc sandstone.

The lower slaty rocks of Llandeilo age are likewise succeeded in La Sarthe by an arenaceous group, represented by 8 and 9 of the previous woodcut. In general, this division exhibits, in ascending order, conglomerates, white and reddish siliceous sandstones, with some subordinate beds of "ampelite" schists containing Graptolites, chiefly the G. colonus and the G. testis of Barrande. The position of these beds is probably the same as that of the graptolite schists of Dalecarlia and parts of Sweden. They agree also, according to de Verneuil, with the

* Crustacés Fossiles. Paris, 1822.

† De Verneuil and Rouault, Bull. Soc. Géol. Fr. 2nd ser. vol. iv. p. 320.

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great schistose member of the American Silurians called the "Hudson River group," which is equally characterized by graptolites, and overlies the Trenton limestone or Llandeilo flags, the equivalents, as above said, of the slates of Angers. As to the siliceous sandstones wherein the schists are enveloped, they are identical with the rocks of Jurques, Gahard, and May in Normandy, placed by French geologists without hesitation on the parallel of the Caradoc sandstone of Britain.

In some districts the sandstone is so ferruginous as to be the seat of iron mines, and the ore in parts is of an oolitic structure: trilobites are found in it.

The sandstones are not rich in fossils; but where I have examined them in company with M. de Verneuil, they contain the British species, Bellerophon bilobatus, with Conularia pyramidata, some species of Dalmannia, Homalonotus Brongniarti, and H. (Plesiocoma) rara; the last-mentioned fossil occurs also in the Lower Silurian of Bohemia and Spain.

Like the lower and larger portion of my original Caradoc formation in Britain, with which the Bala rocks are now identified, this group of sandstones and schists is also connected by its fossils with the inferior slates.

Overlying the above-mentioned strata, there is, in France, an upper course of ampelite schist, which, though often confounded with the lower, must be separated from it. These upper ampelitic schists (11 of the section), being black and occasionally bituminous, have, as usual, given rise to wasteful searches after *coal*. They are distinguishable from the inferior masses by containing concretions of black limestone with a brilliant fracture, and by certain imbedded fossils. The most characteristic remains are Graptolithus priodon, with some Orthocerata, including O. pelagium, O. gregarium, and the Cardiola interrupta*. As this last-mentioned species is chiefly an Upper Silurian fossil in Britain, and occurs in Bohemia at the base of that division, it might seem fair, in the first instance, to consider this French deposit as of like age. At the same time we must observe, that Cardiola interrupta, on the presence of which the comparison was drawn, is occasionally, though rarely, found in the Lower Silurian both of Britain and Bohemia. Whilst, therefore, this zone is clearly recognized, through extensive districts of France, as the highest of the rocks which are referable to the Silurian epoch, it is by no means an equivalent of the great British formations of Wenlock and Ludlow. We must, indeed, recollect that in Britain, as in Bohemia and Sweden, such schists, with Cardiola interrupta and Graptolites, underlie limestones with the well-known fossils of Wenlock, Dudley, and Gothland.

In France, therefore, the ascending series of strata is very different from that of Britain. The Upper Silurian, as a whole, is wanting; the

* See an account of the extension of this zone of ampelite schists and its intercalated minerals, by M. de Boblaye, Bull. Soc. Géol. France, 1 ser., vol. x. p. 227.

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succession being analogous to that of parts of Russia and Germany where the Lower Silurian is succeeded by Devonian rocks. (See Ch. 14, 15, 16.)

Devonian Rocks.—France is by no means poor in Devonian equivalents. Numerous species of fossils derived from the strata 12 and 13 of the foregoing diagram have been compared by de Verneuil with those of the lower shelly greywacke of the Rhine and the limestone of the Eifel, and he has found that many of them are identical. Among these, the broad-winged Spirifer macropterus, the Terebratula Archiaci, Grammysia Hamiltonensis, and Pleurodictyum problematicum are striking Devonian forms, unknown in any Upper Silurian rocks. The great number of species common to the limestones of La Sarthe*, and Nehou† in Normandy, and the lower fossiliferous band of the Rhine, naturally leads to the belief, that the French and Prussian formations are contemporaneous. If this view be adopted, we must presume that France possesses no proper and full equivalent of the English Middle Devonian limestone, but simply the inferior portion of the group, called by Dumont the "Système Rhénan," and the upper member as seen in the Boulonnais.

Having established the connexion between the Devonian rocks of the West of France and the lower portion of the group in the Rhenish provinces, de Verneuil observes, that in such a consecutive development we might expect to meet with some species which on the continent of Europe and the British Isles are considered to be Silurian; and such is the case. Thus, Bronteus Brongniarti, Capulus robustus, Terebratula eucharis, T. Haidingeri, Atrypa reticularis, Orthis Gervillei, Leptæna Bouei, L. Bohemica, and L. Phillipsi are found in the Devonian of France, and also in the uppermost Silurian of Bohemia. At the same time, Pentamerus galeatus, Atrypa reticularis, with the corals Heliolites interstincta, H. Murchisoni, Stenopora fibrosa, and Chonophyllum perfoliatum, also are common to the Upper Silurian of England or Sweden and the Lower Devonian of France.

The Devonian group of Brittany and the West of France is also usually curtailed, like the Silurian, of its superior members,—those which, in the Rhenish provinces, are so fully developed between the above-mentioned rocks and the base of the Carboniferous system.

In the "Bas Boulonnais," however, we meet with a fair representative of the Upper Devonian, rich in fossils, and of which, in 1840‡, I published a short memoir. It is there immediately overlaid by the carboniferous limestone, and both of the formations extend into Belgium and the Rhenish provinces, occupying the same relative position§.

* De Verneuil and Rouault, *ante*, p. 433.

† At this locality abundance of Devonian fossils were obtained by the late M. de Gerville, and distributed among his friends. Both trilobites and shells are found there; and among the latter are the common Devonian species, Spirifer heteroclytus, Athyris concentrica, and Calceola sandalina. More than 45 species of Brachiopoda were lately found here by Mr. Davidson.

‡ At that time the exact relations of the strata had not been determined, and I was deceived as to the nature of a small imperfect body, probably a coralline, which was taken for a graptolite. Bull. Soc. Géol. France, vol. xi. p. 229. M. Delanoue, who has recently published a small geological map of this country, has ascertained by sinkings, that the Devonian deposits range underground towards Bethune and Arras. Bull. Soc. Géol. Fr. 2nd ser. vol. ix. p. 399.

§ Mr. Austen, whose former labours threw so much light on the real nature of the limestones of Devonshire, has sur-

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This Upper Devonian is everywhere recognized by the abundance of its Spirifers, among which Spirifer disjunctus, Sow. (Spirifer Verneuilii, mihi), and its numerous varieties are the most characteristic. The Productus subaculeatus and Athyris concentrica are also frequently found. The limestone recurs in different bands with dolomites, sandstone, and schist, composing a group which has its full equivalent, as already shown, in Belgium and on the Rhine. Like the Lower Devonian of Brittany, the rocks in the Bas Boulonnais have a strike from the west-north-west to east-south-east, but are soon overlapped, first by the carboniferous, and then by the cretaceous and younger deposits.

Though the Devonian rocks of France are of no great vertical dimensions, and not comparable in thickness to the deposits of like age in Scotland, England, or the Rhenish provinces, they are of considerable economic importance, particularly in certain schistose and arenaceous districts which they traverse, and where their limestone is much used in agriculture. At the extremity of the peninsula of Brittany these rocks appear in the Bay of Brest.

Carboniferous Rocks of France.—In this work it is impossible here to convey an adequate idea of the Carboniferous group, particularly that portion of it as developed in the extensive upper coal-fields of France. The following few observations relate therefore only to the lower and calcareous member which immediately succeeds to the subjacent rocks; the great coal-fields of Valenciennes in the north, and those of St. Etienne and Autun in the south, being consequently unnoticed. In the Bas Boulonnais, as before observed, no gap nor omission exists in this portion of the series; for the Upper Devonian is at once followed by the Carboniferous Limestone, with many of its large Producti and

veyed this district of the Boulonnais in detail, and has endeavoured to show that its lowest strata (limestones, dolomite, &c.) represent the rocks of the Eifel, and are charged with the same species of corals, and many of the same mollusks, which are so well known in Devonshire and on the Continent. The overlying calcareous courses with shale he considers to be equivalents of the Upper Devonian as exhibited at Petherwin (see pp. 294, 299); the comparison being further sustained by a description of certain flag-like, light-coloured sandstones, charged with plants, and the same species of Cucullæa—C. trapezium and C. Hardingii, Sow.—as the yellow sandstones of Marwood and Baggy Point in North Devon, which sandstones constitute one of the upper members of the Devonian rocks. Mr. Austen's section does not exhibit any representative of the Spirifer-Sandstein or Lower Devonian of the Rhine. But the rest of the Devonian rocks of the Rhine and Belgium have, according to his view, their equivalents in the North of France. (Quart. Journ. Geol. Soc. vol. ix. p. 231.) This view is, however, not adopted by de Verneuil, de Koninck, and others, who continue to view the chief masses of the Boulonnais as Upper Devonian.

Mr. Austen has successfully dwelt upon the complete conformity and passage upwards of these Devonian rocks of the North of France into the lower carboniferous strata with their two bands of limestone and interstratified seams of coal, and has made some ingenious theoretical suggestions, founded on the presumed omission of the intermediate secondary rocks, respecting the probable extension westwards, even perhaps to England, of these beds of coal (which have already been opened out near St. Omer), so that they may eventually be found beneath the tertiary and cretaceous deposits of the London basin. (See Quart. Journ. Geol. Soc. Lond. vol. xii. p. 38 *et seq.*)

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other typical fossils. But in Brittany and the West of France, the lower carboniferous deposits rest at once upon the Lower Devonian; as is seen between Sablé and Juigné (p. 434), and at the coal-pits of Fercé. The anthracitic group of the department of the Sarthe (14, 15, 16, of the preceding section) is composed of conglomerates, sandstones, shale, coal, and limestone, all unquestionably belonging to the Carboniferous series, of which they constitute a lower member. In the West of France, as at St. Pierre-la-cour, between Laval and Rennes, they are unconformable to the superjacent coal-fields.

A like physical arrangement has already been alluded to as occurring throughout Germany. True carboniferous limestone, with large Producti, was described by Professor Sedgwick and myself at Hof, in Bavaria*, as being there inclined conformably with the Devonian, on which it rests, and unconformably to the horizontal coal-fields of Bohemia. Similar physical relations led E. de Beaumont to group the inferior carboniferous division with the lower paleozoic rocks to which it is conformable, though their respective organic remains are so very distinct. The geologist, who combines stratigraphical with zoological evidences, is therefore bound to state, that the dislocations of the older rocks on the Continent have occurred at periods different from those of formations of the same age in Britain and America. In both the latter countries the great superjacent coal-fields *have* partaken of the movements which affected the limestones whereon they rest. Thus we are still further confirmed in the belief, that all fractures of the crust of the earth are local phenomena only.

As the strata containing large Producti (Sablé, Fercé, Juigné, La Bazouge, &c.) were shown to be truly of carboniferous age, their fossils being absolutely those of the mountain limestone of England, it followed that many other considerably metamorphosed rocks in the south-east of France, but in which such fossils were detected, must also be referred to the same era of formation. Thus de Verneuil and Jourdan have proved, that the schists, slates, and quartz rocks of Central and Eastern France, particularly in the department of the Haute Loire (Roanne to Lyon), which, from their crystalline aspect, had been grouped with those of a much older epoch, are clearly to be classed with the Carboniferous rocks. Though in parts highly altered, and having a very antique and crystalline aspect, they have been found to contain the well-known fossils of the Coal period, Productus Cora, Chonetes papilionacea, Spirifer bisulcatus, Orthis crenistria, Goniatites diadema, &c.

It was in the northern extension of this chain of hills from Thiers to Cusset near Vichy, where the schists have a still more ancient character and are pierced by numerous porphyries and syenitic rocks, that, by the help of a few fossils, I was enabled to satisfy myself that the slaty rocks on the banks of the Sichon also belonged to the Carboniferous era†.

* Trans. Geol. Soc. Lond., 2nd series, vol. vi. p. 298. pl. 23. f. 15.
† Quart. Journ. Geol. Soc. Lond. vol. vii. p. 13.

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The Permian rocks of France may be disposed of in few words, for they are very inadequate representatives of the diversified and complex assemblage of strata which constitute the Permian of Russia, Germany, and Britain. The lower portion of a series of red rocks in the Vosges Mountains, usually known as the "Grès des Vosges," is considered by E. de Beaumont and myself to be of this age; and it has also been shown how other red sandstones, near Lodève in the South of France, may from their plants be classed as Permian. Professor Coquand has, however, recently described a succession of strata in the same tract, which he also views as being of Permian age*; thus confirming the opinions of M. Adolphe Brongniart and the authors of 'Russia and the Ural Mountains†.' But nowhere within the limits of the country is there any limestone to represent the great calcareous centre or Zechstein, and the group is therefore wanting in those animal remains which constitute its essential distinctions.

In the hard and subcrystalline rocks of the South of France, which lie to the south of the great granitic plateau of that region (*i. e.* the Montagne Noire, between Lodève and Pezenas), no clear succession of the older rocks has been determined, and until very recently they were considered, to a great extent, unfossiliferous.

Within these few years, however, MM. Fournet and Graff discovered at Neffiez near Pezenas‡ a very singular small *oasis*, in which there occur thick masses of green slate with large Lower Silurian Asaphi, succeeded by other beds laden with several characteristic Lower Silurian fossils, whilst higher strata contain Cardiola interrupta and Graptolites. Then there are red limestones charged with unequivocal Upper Devonian types, as recognized by de Verneuil; these are Goniatites amblylobus and Cardium palmatum of Westphalia, Nassau, and the Eifel. This rock is also identical with the "marbre griotte" of the Pyrenees, which the lamented Leopold von Buch classed as Devonian. Again, we have in this one little spot, true carboniferous deposits; for, though there are only a few beds of their lower members, the fossils are unequivocal; viz. Productus gigas, P. semireticulatus, Euomphalus acutus, Caninia gigantea, &c. The series is even terminated by some workable beds of coal.

Such, says de Verneuil, is the paleontological order of the strata, if we look only to the fossils, and compare them with those of all other known countries in the world.

But, whilst this is the universal and normal order in America, Asia, and Europe, these members of the series, so distinct elsewhere, were at one time supposed to be physically intermixed at this little anomalous spot of Neffiez! But MM. Fournet and Graff, who had called attention to this apparent intermixture of Silurian, Devonian, and Carboniferous fossils, no longer maintain the opinion they at first expressed.

* Bull. Soc. Géol. France, 2nd series, vol. xii. p. 128; and xiv. p. 13.
† See 'Russia and the Ural Mountains,' vol. i.
‡ Bull. Soc. Géol. France, 2nd series, vol. viii. p. 44.

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In fact, the tract has manifestly been subjected to violent dislocations, and my associate de Verneuil has always thought, that the apparent anomaly is due to one of those inversions or reversals known in the Alps, America, and many other regions, and to which I have already called attention in my remarks on Britain and Germany (pp. 107, 160, 428).

The paleozoic formations again protrude to the surface in the Corbières to the south of the plains of Languedoc, and rising from beneath the younger deposits, they also, as has been long known, form a central portion of the Pyrenees. In that chain, the altered limestones, or "Marbres Griottes*," which occur as concretionary masses in the schists, and are charged with goniatites, are unquestionably Devonian. The schists of Gedre, between St. Sauveur and Gavarnie, and also at Les Eaux Bonnes and other places noticed by M. Leymerie†, contain other fossils of the same age.

Just as in the Eastern Alps, the Ural, and many mountain-chains which have undergone much metamorphism, the observer fails to detect here the equivalents of the Lower Silurian Rocks‡. But in a few spots, the Pyrenees afford traces of one member of the system, as characterized by Graptolites, Cardiola interrupta, and the Orthoceras Bohemicum and O. gregarium,—fossils which have already been spoken of as probably representing the base of the Upper Silurian division. In the absence then of Lower Silurian rocks, the Pyrenees present a strong contrast to the "Montagne Noire," near Neffiez, where some of the largest trilobites of that age have been found.

Paleozoic Rocks in Spain, Portugal, and Sardinia.—To the south of the great chain of the Pyrenees, where several of their formations occur in a more or less crystalline state, the Lower Paleozoic or Silurian rocks have much the same development as in France. Our acquaintance with the order of these rocks in Spain is chiefly due to the researches, during the last five years, of my colleague de Verneuil. For, whilst it is true that living Spanish and French geologists and mineralogists of ability, such as Ezquerra del Bayo, Casiano de Prado, Schultz, and Paillette, had made themselves well acquainted with the physical and lithological features of many tracts in which the older rocks prevail, and that an eminent French mining engineer, Le Play, had published a sketch of the mineral structure of the Sierra Morena, it was only by a personal examination of the imbedded fossils of the strata in each chain,

* This "marbre griotte" of the valley of Campan is well described by M. Dufrénoy.

† See Bull. Soc. Géol. France, 1856, where the list of fossils given by M. de Verneuil would lead us to suppose that the rocks near Les Eaux Bonnes belong to the Lower Devonian.

‡ Bull. Soc. Géol. Fr. 2 sér. vol. i. p. 137.

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that the relative age of the rocks was at length fixed, and correct comparisons established*.

A glance at the map shows that the Peninsula is marked by dominant chains of mountains more or less parallel, trending from west-south-west to east-north-east, and separated from each other chiefly by enormous basins of tertiary age, which, though at much lower levels, are still at considerable heights above the sea, and constitute, on the whole, what Humboldt has termed a great plateau†.

Let us first say a few words on the chief central ridge of the kingdom, the Guadarama, which passes to the north of Madrid. Casiano de Prado, the zealous Spanish geologist, who is charged with the execution of the geological map of the province of Madrid, has shown that the gneiss and other crystalline schists and subordinate limestones are pierced by granites, and, being much altered, rise to heights exceeding 7000 feet. These are flanked by schists and siliceous sandstones, which are classed as Lower Silurian, because they contain the Cruziana or Bilobites, a fossil which occurs in rocks of that age in France and Britain.

A suggestion has indeed been made by Barrande, from an inspection of three imperfect heads of the trilobite Ellipsocephalus, collected by Casiano de Prado, that the primordial zone is also present in the Peninsula. However this may be, other Silurian rocks of the lower division, and more clearly determinable as such by their fossils, exist in the Sierra Morena, and partially in the mountains of Toledo and those of

* This observation has reference solely to the order and classification of the stratified rocks; for, in reference to mineralogy and other departments of geological science, a vast number of works and memoirs have been written in the last century, by native and foreign authors. See de Verneuil and Collomb, Coup d'œil sur la Constitution Géologique de quelques Provinces de l'Espagne, Appendice Bibliographique, Bull. Soc. Géol. Fr., 2nd ser., vol. x. p. 138, where a very copious list of authors is given, comprising upwards of 160 publications in the last hundred years. At the meeting of the British Association for the Advancement of Science in 1850, I presented, on the part of M. de Verneuil, what I believe to have been the first geological map of the whole Peninsula, accompanied by a short notice. Since that time my colleague has twice revisited Spain. The high antiquity of the crystalline rocks of Gallicia is affirmed on the authority of M. Schultz, who has made a geological map of that province, and is completing a beautiful map of the Asturias. The tracing of Silurian rocks into the Toledo Mountains is due to the zealous researches of M. Casiano de Prado, to whom we also owe the proofs that the quicksilver mines of Almaden are in Lower Silurian rocks. Many of the fossils (chiefly Devonian) from the North of Spain were first found by M. Paillette, whose description of the rocks of that age is given in the Bull. Soc. Géol. France, vol. ii. p. 439. A sketch of a geological map of Spain was also published by M. Ezquerra del Bayo in Leonhard and Bronn's Jahrbuch, 1851. In his last excursion M. de Verneuil was accompanied by M. Collomb, who has likewise given a sketch of the general views they then acquired of the structure of the Peninsula, in the Bibliothèque Universelle de Genève.

† The mean altitude of the Plateau of Old Castile, for example, is from 2150 to 2200 English feet, and that of New Castile about 300 feet less.

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Arragon. In crossing the Sierra Morena from Almaden on the south to Cordova on the north, de Verneuil recognized an ascending order. The inferior strata consist of schists and some intercalated dark limestones, with quartzose sandstones; the latter not unlike the British Stiper Stones. (See p. 39.) These, being the hardest and least decomposable portions of the strata, form the summits or peaks of the low ridges, and clearly exhibit the strike or range of the masses, which is from east 10° north, and west 10° south. The celebrated quicksilver mines of Almaden occur at the foot of one of the quartzose ridges of this age, as determined by M. Casiano de Prado*, who has published in the 'Bulletin' of the Geological Society of France (vol. xii. p. 182) a geological map of this tract. The same zealous explorer has also traced the continuity of Lower Silurian rocks from the Sierra Morena into Gallicia; the range passing through Estremadura and by the Sierras of Gata and Francia. Most of the mountains which, extending from S. to N., form the boundary between Spain and Portugal, may thus be considered to be of the same age. The Lower Silurian rocks of the Sierra Morena range eastwards to the city of Alcarraz, where they subside under the secondary formations of Murcia. The long chain of the Sierra Morena, which extends from Alcarraz to Cape St. Vincent, is separated from the metamorphic and crystalline coast-range of the Mediterranean by a mountainous country composed of secondary and tertiary rocks. The age of this coast-range, of which the Sierra Nevada is so prominent a feature, is still doubtful. One of the mineral characteristics of that lofty region is, that it contains immense masses of limestone which occasionally are dolomitic, and rise into lofty peaks, unlike any portion of the outline in the Silurian and Devonian rocks of the Sierra Morena. It has indeed been suggested by M. Pellico, that the southern coast-chain may be of Silurian age, on account of the existence of very imperfect orthoceratites and corals. Judging, however, from the mineral structure of the deposits and the nature of the greenstones which intrude into them, M. de Verneuil is disposed to think that these metamorphosed rocks will prove to be of Triassic age. It is well known that these rocks are the sites of some of the richest mines of argentiferous galena, particularly near Carthagena, in the Sierra Almagrera, as well as in the Sierra di Gador and at the foot of the Sierra Nevada.

The fossils found in the Sierra Morena and the Toledo Mountains occur usually in black shivery schist. The most prevalent is perhaps the Calymene Tristani; but recently many other well-known French forms of trilobites, in all about twenty species, have been detected†,

* The mercury of Almaden is said not to form veins, but to have impregnated the vertical strata of quartzose sandstone associated with carbonaceous slates. The occurrence of mercury with such rocks is still more remarkable in the Asturias, where mines of mercury are worked in coal strata.

† In an examination by Casiano de Prado, Eusebio Sanchez, and E. de Ver-

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including Illænus Lusitanicus? or I. Salteri, Asaphus nobilis, Calymene Tristani, C. Arago, Phacops socialis, P. Dujardini, Dalmannia socialis, and D. Phillipsi, Barr.; Trinucleus Goldfussi, Barr.; Homalonotus (Plesiocoma) rarus, Placoparia Tournemini, Orthoceras duplex, Bellerophon bilobatus, Redonia Deshayesiana, &c.; also occasionally Graptolites have been discovered, of species well known in Brittany, Normandy, Bohemia, and Saxony.

Now, whilst most of these fossils are also found, as has been stated, in the slaty schists of Angers and Vitré, in France, which the French geologists have mapped as Lower Silurian, several are identical with Bohemian species, published as of the same age by Barrande. It is also well worthy of notice, since the fossils generally resemble so much those of Central Europe, that the very common British species, Bellerophon bilobatus, and the remarkable cephalopod, Orthoceras duplex (so characteristic of the Lower Silurian fauna of Scandinavia and the North of Europe), should also be found, as M. de Verneuil remarks, in this southern parallel. Some of the Silurian fossils enumerated were first discovered by M. Casiano de Prado, near Molina, in Arragon. They have subsequently been there traced by the same geologist, and also along the eastern borders of New Castile, where they occur in black graptolite schists which jut out from beneath the secondary deposits. These Silurian schists have further been followed by the same author in the mountains of Checa, Horca, Origuela, and Monterde.

If any Upper Silurian rocks can be said to exist in Spain, they consist, as in France, only of thin courses of black schist, with spheroidal calcareous concretions in which Graptolites occur, together with the Orthoceras Bohemicum and O. styloideum of Barrande, and the British Cardiola interrupta. Such rocks, faintly exhibited in parts of the Sierra Morena, are also seen on the south flank of the Pyrenees, near Ogasa and San Juan de las Abadesas, where they are recognized* by the presence of Cardiola interrupta and Orthocerata. It is also supposed that a band of siliceous limestone pierced by *elvans*, or granitic dykes, and which extends along the south side of the chain from Gerona, by Hostalrich, to Barcelona, may be referred to the same age; Orthocerata having been found in it near the last-mentioned city by Mr. Pratt, who has explored large tracts in Spain†.

Devonian Rocks in Spain.—Devonian rocks are developed in the Sierra Morena north and south of Almaden, and occur in several repe-

neuil. For details see the memoir of Casiano de Prado, de Verneuil, and Barrande. Bull. Soc. Géol. Fr. 2 ser. vol. xii. p. 964.

* By M. de Verneuil and M. de Lorière. The fossils near San Juan de las Abadesas were discovered by M. Amalio Maestre; they have been quoted by Prof. Leymerie, from near St. Béat on the north side of the Pyrenees, and they exist also in Sardinia.

† For Mr. Pratt's notice of the Orthocerata, see Quart. Journ. Geol. Soc. Lond. vol. viii. p. 270.

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titions troughed by Lower Silurian rocks; the fossils lying generally in sandstones, or in small bands of impure limestone. The most characteristic species are: Productus subaculeatus, Leptæna Dutertrii, Spirifer Verneuilii, S. Archiaci, S. Bouchardi, Orthis striatula, Terebratula reticularis, T. Orbignyana, T. concentrica, Phacops latifrons, &c. All these but one (Terebrat. Orbignyana) are common fossils at Boulogne; and there are many others which are well known in French and German localities, besides some species peculiar to Spain. In the southern parts of Cuenca, near Hinarejos, de Verneuil and Collomb also detected deposits containing Lower Devonian fossils, including the Spirifer macropterus of the Rhine*; and, in 1852, the equivalent deposits were traced at the eastern extremity of the Guadarama range between Atienza and Siquenza, by de Verneuil and de Lorière.

Whilst the western parts of the Sierra Cantabrica, extending from the high road from Leon to Oviedo, are now known to be composed of quartzose and schistose strata of Silurian age, M. C. de Prado having detected graptolites in them, the medial part of this chain presents a very rich development of Devonian deposits. These rocks consist of red sandstone, shale, and grey limestones, which, owing to powerful dislocations, assume bold and peaked forms, visible at great distances from the plains of Castile. They are as prolific in mineral wealth as in organic remains; the iron of Mieres and Sabero being extracted from them†. Thanks to the labours of Schultz, Casiano de Prado, Paillette, de Verneuil, and d'Archiac, the successive formations of these countries are now becoming much better known.

Carboniferous Rocks of Spain.—Proceeding to the east, the Devonian rocks of the Sierra Cantabrica are succeeded in the Asturias by the richest coal-field in Spain. Its lower beds consist of massive limestones, having so much resemblance to the Devonian rocks on which they lie, that, except for their respective organic remains, they could with difficulty be separated. The fossils are, however, decisive of the superior rock, for among them are several well-known British species of Productus, such as P. semi-reticulatus, together with Spirifer Mosquensis, and even Fusulina cylindrica, the characteristic foraminifer of the carboniferous limestone of Russia. Above these masses, beds of coal

* M. de Verneuil has identified nearly 80 Devonian species, from Sabero in Leon, and from Ferrones and Aviles in the Asturias, which ought, he says, to be places of pilgrimage for all collectors. Of the works on this region, see, 1st, 'Reseña geognostica de principado del Asturias, vistazo geolog. sobre Cantabria,' per G. Schultz, Insp. Gen. de Minas. 2nd, 'Recherches sur quelqu'unes des rôches des Asturies, et les fossiles qu'elles contiennent,' par Paillette, de Verneuil, et d'Archiac; Bull. Soc. Géol. Fr., 2nd series, vol. ii. p. 439. 3rd, 'Sur les Environs de Sabero (Leon),' par Casiano de Prado et de Verneuil; Bull. Soc. Géol. Fr. 2nd ser. vol. vii. p. 137.

† Though the coal of Sabero is *apparently* included among the Devonian rocks, M. Casiano de Prado thinks that this appearance may be due to inversion and folding of the various strata; so much has this paleozoic tract been convulsed.

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first begin to alternate with other and smaller courses of limestone; and therefore in Spain as in Russia, and usually in Scotland, the carbonaceous portion is subordinate to the lower member of the group. Then follow conglomerates and sandstone with fossil plants, said to have a thickness of 10,000 feet, and which, probably representing the millstone grit of Britain, are copiously charged with coal; about eighty beds of it having been recognized in strata, for the most part vertical.

The limestones that form the inferior limit of these carboniferous deposits truly vindicate the propriety of the old English name Mountain Limestone, for they rise to the highest points of the Cantabrian chain, and constitute the mountains of Cabrales and Cobadonga, as well as the Peaks of Europe (Picos de Europa). They also advance to the sea near Ribadesella, and penetrate on the east into the provinces of Santander and Palencia*. The last-mentioned of these provinces has during the last three years undergone a special and laborious survey by M. Casiano de Prado, who is about to publish a map founded on his trigonometrical observations, which must prove of signal advantage to this rich mining region. The same untiring and successful explorer has demonstrated, that in no other part of Spain is the carboniferous limestone so rich in fossils, inasmuch as he has detected at least 100 species in this one tract.

The carboniferous deposits of the Sierra Morena range along the southern part of that chain. Like similar formations in the north of Spain, their lower beds generally contain limestones, in which occur the same species of Productus and many marine fossils that are known in other regions. The coal is chiefly associated with overlying conglomerates and sandstones; some of it, however, as in the Asturias, is said to lie in the calcareous series. The best coal-fields of this southern region are at Villa Nueva del Rio near Seville, and in the neighbourhood of Belmez, between Almaden and Cordova, where the strata are highly inclined.

On the flanks of the crystalline schists, probably metamorphic, which form the Sierras east of Burgos, towards Brieva de Guarros and Escaray, are also masses of sandstone and shale, with impressions of plants and traces of coal, associated, as in the other Spanish coal-fields, with a few marine fossils. These rocks are mentioned only to show, how generally the same paleozoic succession prevailed over the Peninsula before the country was thrown up into those ridges which now form the lines of separation between its different provinces.

* During the summer of 1852, MM. de Verneuil, Casiano de Prado, and Lorière ascended one of these lofty peaks of Mountain Limestone, and found, by barometrical observation, that it was 2500 metres, or about 7750 English feet, above the sea. It was covered with snow on the 1st August. In the summer of 1856, M. Casiano de Prado ascended the highest of all these peaks, and determined its height to be 2650 metres, or 8171 English feet!

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Whatever be their direction or inclination, the Silurian, Devonian, and Lower Carboniferous rocks of Spain have all been conformably, and apparently simultaneously elevated, as in France.

The existence of Permian rocks in Spain is unknown; no fossils of that age having yet been found in so southern a part of Europe.

Although this work does not treat of the secondary rocks, it is due to my eminent associate de Verneuil, and his fellow-traveller, M. Collomb, to state that, besides tracing Jurassic and Cretaceous deposits, they detected true Muschelkalk fossils near Mora on the Ebro, thus clearly demonstrating the existence of Trias in the Peninsula*.

Silurian and Carboniferous Deposits in Portugal.—Geologists are indebted to the late lamented Mr. Daniel Sharpe for nearly all they know of the real structure and succession of the sedimentary rocks of the kingdom of Portugal, whether of paleozoic or secondary age†.

Of the former, two notable examples have been pointed out, and probably many more will be detected, in addition to another case to be presently noticed. The first noticed was at Vallongo, in the immediate environs of Oporto. There, the Lower Silurian rocks, precisely of the same mineral type as those of France and Spain, and including the same fossils, together with two or three British forms and some new species, rise up in highly inclined and vertical strata; and, as at Angers and other places, are quarried for roofing slates.

An anomalous arrangement of the lower and higher deposits is, however, there apparent. The coal-field of Vallongo, which has supplied a considerable portion of the city of Oporto with fuel, and in which are certain plants not distinguishable from those of the Carboniferous era, dips under the Lower Silurian schists with their characteristic trilobites! Now, if this had been really the normal position of the plant-bearing strata, we should have to believe in the existence of an ante-Silurian flora, composed of the same terrestrial vegetation as that which, in other regions, we find only when we approach to the horizon of the great coal-fields. Believing fully in the accuracy of Mr. Sharpe's sections, I think, however, from his own faithful description of this district and the region to the south of it, that we may without difficulty surmise how this apparent anomaly has been brought about. The Lower Silurian rocks and the contiguous coal strata (for the coal is not found within the body of the lower slates) are both situated between two ranges of eruptive rocks; the one on which Oporto stands being granite,

* Some badly-preserved fossils of Triassic age had been previously observed by Casiano de Prado, de Verneuil, and de Lorière, at Roquela, in the mountains of Albaracin. I look forward with much satisfaction to the speedy publication of the Geological Map of Spain by M. de Verneuil, who in the meantime has given to the public, in conjunction with M. Collomb, a valuable table of the chief altitudes of this rugged and rocky region. See Comptes Rendus de l'Acad. des Sciences, vol. xliv. p. 1299.

† See Quart. Journ. Geol. Soc. Lond. vol. v. p. 142.

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and the other, to the east, syenite. On the flanks of the granite of Oporto, micaceous schists abound, which, if metamorphic, may be of any age. But, even if these be of ante-Silurian date, we have simply to imagine a trough of coal, of the true carboniferous date, placed between these schists, on the one hand, and the clay-slates with Lower Silurian fossils, on the other, and then by a movement, of which we have many well-authenticated examples both in Europe and America, this trough has been placed in an inverted and dislocated position.

The enormous length of time which must have elapsed between the accumulation of the Lower Silurian and the formation of the Devonian rocks, and during which interval we have no evidence of land plants having appeared, forbids us, indeed, to adopt the view of an infra-Silurian coal-field, until we have exhausted every other means of explaining the anomaly.

Thus, the plications of the strata in Belgium, as delineated by M. Dumont, those in Westphalia mentioned in this volume (p. 429), or those in North America (p. 465), explain how strata really inverted in one place, may be followed until they resume their regular order. Wedged in, as these Silurian and Carboniferous masses of Portugal are, between two flanking parallel ridges of eruptive rock, it was no doubt difficult to detect their regular order; though, even in describing a transverse section from Oporto to Aveiro, Mr. Sharpe himself states, that clay-slates, lying on gneissose and micaceous schists, are surmounted by carbonaceous shale and red sandstone. This is, I conceive, the natural order; because even in the adjacent districts of the north of Spain, to which the author first pointed attention, as being likely to contain Silurian rocks, there are no traces whatever of anthracitic coal-fields beneath or associated with such ancient rocks; all the carboniferous deposits of that region being, as previously stated, in their usual and normal position.

Now, whilst the first edition of this work was printing, Mr. Sharpe communicated to the Geological Society of London* the discovery of fossils, accompanied by important observations made by M. Carlos Ribeiro, which show the prolongation of the same axis of Silurian rocks from north-north-west to south-south-east, far beyond the Douro. The rocks in question form, in fact, the crest of the Serra de Busaco, on which Wellington and Massena first tried their strength, and thence extend to the south-south-east beyond the river Mondego† into the Serra de Mucella. During the greater part of their course, the Silurian rocks are surrounded or flanked by older unfossiliferous masses, con-

* Quart. Journ. Geol. Soc. Lond. vol. ix. p. 135.

† The author craves pardon of the reader for stating, that when a young Ensign in the 36th regiment (sixteen years of age), he disembarked, on the 1st of August, 1808, at the mouth of this river Mondego, and close to the boat from which Sir A. Wellesley first stepped on to the shore of the Iberian Peninsula.

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sisting of mica and chlorite schists with clay-slate, &c. These crystalline rocks are at once followed by dark brown indurated shales, somewhat slaty, which abound with Lower Silurian fossils, among which Mr. Sharpe has recognized numerous species of Leptæna and Orthis, with trilobites, many of them previously undescribed. He has, however, identified the most characteristic of the trilobites with species well known elsewhere; Trinucleus Pongerardi, Calymene Tristani, and C. Arago of Brittany, also Phacops socialis of Bohemia. The lower fossiliferous rock of Busaco therefore obviously represents the oldest zone in France and Spain known to contain remains, and identical with that described by Mr. Sharpe at Vallongo near Oporto. It is surmounted, and chiefly along the middle of the ridge of Busaco, by a band of hard ochreous shale, frequently altered by eruptive masses of greenstone trap, and generally breaking up into prisms; the bedding being scarcely distinguishable. It is probably equivalent to the sandstone of May in Normandy. This rock is full of small corals, such as Favosites? fibrosa, besides species of Retepora?, also many simple plaited Orthides, and some trilobites common to the subjacent deposit; the whole of the evidence proving clearly, that it is simply a superior member of the Lower Silurian group. Again, the uppermost of these Silurian rocks in Portugal is apparently the same zone we have been considering in Spain and France; viz. a bluish shale or argillaceous schist, containing the well-known British fossils Graptolites Ludensis and Cardiola interrupta, with other mollusks, also numerous crushed specimens of Orthoceratites. All these fossils, according to Mr. Sharpe, are referable to the Wenlock shale, or inferior portion of the Upper Silurian.

Now, these Silurian rocks are overlaid unconformably by a deposit of true carboniferous age; the shales and sandstones being full of ferns and other plants, of species common in the coal deposits of France and Germany. Thus, when traced out, the apparent anomaly at Vallongo is resolved by a case perfectly analogous to the examples given in previous parts of this work, and the order of succession is proved to be the same as in other regions.

Sardinia and Upper Italy.—Extending our inquiry eastwards from Northern Portugal and Central Spain to like parallels of latitude on the other side of the Mediterranean, we again meet in Sardinia with a similar succession of paleozoic deposits. Geologists owe this determination to the researches of General de la Marmora, so long favourably known to geographers for his beautiful topographical map of that island. Judging from certain Orthidæ and Orthocerata, which this author sent to me in the year 1848, I have for some years had no doubt that Silurian rocks existed in Sardinia, as laid down by Collegno, in his geological map of Italy. I have since been informed by M. Barrande, who has personally inspected the rocks and fossils in the southern part of the

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island, near Flumini Maggiore, that in his opinion both Lower and Upper Silurian rocks are there present.

The work by General de la Marmora, which I anticipated in the first edition, has now appeared, accompanied by an elaborate map; and it is now demonstrated by Professor Meneghini of Pisa that several of the fossils collected by the General and his assistant M. Vecchi are well-known Silurian forms. Among these may be mentioned Orthis Lusitanica, Sharpe, O. testudinaria and O. vespertilio, Sil. Syst. &c. Other fossils are, on the contrary, Upper Silurian types, such as Orthoceras ibex, O. gregarium ?, Sil. Syst., and several others, besides Cardiola and Avicula.

General de la Marmora informs us, that all these Silurian or other rocks*, and the metamorphic masses with which they are associated, are distinctly surmounted by strata containing anthracitic coal, charged with many of the fossil plants which prevail in the old coal-deposits of other regions. Thus, among the fossils from Seni and Sculo, Professor Meneghini has recognized Pecopteris arborescens, P. dentata, P. unita, P. polymorpha, P. hemiteloides, and several others; with species of the genera Odontopteris, Neuropteris, Sphenophyllum, Annularia, Asterophyllia, Sigillaria, Syringodendron, and an abundance of the well-known Calamites Suckowi.

In fact, the strata in which these coal plants occur, and which terminate downwards in conglomerates†, rest in completely discordant positions on the older rocks, and in this highly altered tract are covered by dolomites of the Jurassic age. The order of the inferior strata in Sardinia is, therefore, the same as elsewhere.

Schists and conglomerates, though not so carbonaceous, but charged with many similar plants to those of Sardinia, have indeed been described by Professors Meneghini and Savi, in the older rocks of Tuscany. At Jano they contain the Productus semireticulatus and other carboniferous fossils. This group of rocks is therefore no longer to be vaguely classed as paleozoic, but takes a definite place, like parts of the Carinthian Alps near Bleiberg, where the same animal remains occur, and thus is proved to be truly of the Carboniferous epoch. These facts, which were unknown when I last published upon the Alps and Apennines‡, are

* It is right to state, that whilst he has seen unquestionable Upper Silurian fossils from Sardinia, which on the part of General de la Marmora I submitted to him, M. de Verneuil is of opinion, that some of the fossils (of which, however, he only saw drawings) are of Devonian age. It is probable, therefore, that the succession will eventually be found to be similar to that of Spain.

† See my Memoir on the Alps, Apennines, and Carpathians, Quart. Journ. Geol. Soc. Lond. vol. v. p. 157, and particularly its translation into Italian by Professors P. Savi and Meneghini, entitled 'Struttura Geologia delle Alpi, degli Apennini e dei Carpazi,' followed by their 'Considerazioni sulla Geologia della Toscana' (Firenze, 1850), in which these distinguished Italian geologists announce the important discovery of the old Carboniferous formation in the hills near Volterra.

‡ Quart. Journ. Geol. Soc. Lond. vol. v. pp. 157, &c.

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most important, and lead us to infer, that the traces of coal which are associated with certain land plants in parts of the Western Alps, are also of the old Carboniferous age. For the conglomerates and schists with which such plants are associated in the Alps are the precise equivalents of the "verrucano" and schists of Sardinia and Northern Italy, and these lie beneath strata of Triassic, Liassic, and Jurassic age.

It has, indeed, been already stated, that rocks containing Silurian, Devonian, and Carboniferous shells occur in the Austrian or Eastern Alps. With these data before us, and looking to the prodigious amount of metamorphism, dislocation, convolution, and inversion to which the component parts of that chain have been subjected in their extension to the west, we can have little difficulty in imagining how the Silurian and Devonian strata have there passed into a crystalline state; while the sole remnants of the carboniferous rocks, identifiable through their organic remains, are the plant-bearing conglomerates and schists of the Valorsine and of certain tracts around Mont Blanc, which have been so twisted up as often to appear to be intercalated with the secondary rocks.

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CHAPTER XVIII.

SUCCESSION OF PRIMEVAL ROCKS IN AMERICA.

ORDER OF THE PALEOZOIC STRATA IN SOUTH AMERICA, THE UNITED STATES, AND BRITISH NORTH AMERICA.

THE researches of geologists have demonstrated that there was a wide diffusion of similar groups of animals over the globe during the primeval periods. A striking proof of this fact is, that many of the paleozoic fossils which we have followed over the various countries of Europe are found to have unquestionable equivalents in the continent of America.

Although the science of the United States has afforded the chief means by which this parallelism has been worked out, I cannot commence even a slight sketch of the older Transatlantic rocks, without first alluding to that masterpiece of natural history, the great work of Humboldt, wherein he gave to mankind a comprehensive view of the structure of the chain of the Andes—the main axis of the western continent.

The oldest of the slaty and quartzose formations, so eloquently described by the illustrious traveller, in whose youthful days fossils were little studied, have been referred, by means of their organic remains, to the Silurian rocks. Following up the inquiries of his precursor, M. Alcide d'Orbigny has shown, in maps and sections, as well as by elaborate descriptions*, that these slaty rocks contain the fossil sea-weed Cruziana (or Bilobites), with Graptolites, Lingulæ, Orthidæ, and trilobites of the genera Asaphus and Phacops (Calymene). He has further pointed out, that these Silurian masses are succeeded by sandstones and siliceous strata probably of Devonian age, and the latter by limestones and other rocks, charged with fossils of the Carboniferous era.

* See 'Voyage dans l'Amérique Méridionale,' tome iii., Partie Géologique, Paris, 1842. In justice to my friend Mr. Pentland, so well known to geographers by his measurements of the high peaks of the Peruvian Andes, around the lofty Lake of Titicaca, let me say, that he was the first person who made me acquainted with the occurrence of Silurian trilobites in the slaty rocks of this chain.

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The Silurian slates and schists form enormous bands; and examples of them are well exhibited on the declivities of the plateau of Bolivia, as well as on the flanks of the Cordillera, extending from Sorata to Illimanni. They are, in most parts of their range, metamorphosed, and in this state extend from Chili on the south* to the Rocky Mountains and the Sierra Nevada on the north. Even in Texas they have been recognized by F. Roemer†. Including the quartz rocks which are associated with them, they constitute the chief matrix of the gold and other metals, so extensively worked along this great chain. (See next chapter.) It has been suggested, that the huge stratified quartz bands described by Humboldt may be the equivalents of the sandstones termed Devonian by d'Orbigny‡, and in which he detected various characteristic fossil shells. But whilst, in the absence of sufficient proof, doubts may be entertained whether these sandstones and quartz rocks of the Andes may be of Upper Silurian rather than of Devonian age, there can be no hesitation in referring the next deposits in ascending order to the Carboniferous or true Upper Paleozoic group. At numberless places, limestones have been observed charged with well-known carboniferous fossils. Several of them, as Productus Cora, Spirifer striatus, Athyris Roissyi, &c., are specifically identical with forms that characterize the strata of this era in Europe and other parts of the globe. As these rocks are associated with, or followed by, accumulations of coal, the general relations of the series are clearly carboniferous.

We now know, therefore (and the recent explorations in California, Oregon, &c., have confirmed the view), that sedimentary deposits of Silurian, Devonian, and Carboniferous age constitute the loftiest ranges and metalliferous plateaux of the American continent. These were, in ancient times, perforated by granites, porphyries, trachytes, and other eruptive matters; and in the modern era are, in some localities, the seat of active volcanic forces.

To bring, however, the older formations of America into an accurate parallel with those of Europe, we must quit the chain of the Andes and the high grounds of Mexico, and turn to the United States and British North America. In large portions of those regions the older strata have been comparatively exempted from igneous disturbances, and as the arrangement of the strata is symmetrical, geologists have been able to demonstrate the order of succession to be the same as that of which numerous proofs have been recited in the preceding pages.

Large masses of the most ancient stratified, crystalline rocks of North America, particularly those constituting the broad, low watershed of Upper Canada, the Laurentine Mountains, are composed chiefly of

* In the admirable work on 'South America,' by Mr. Charles Darwin (1846), the only paleozoic fossils alluded to are those of the Falkland Islands (Upper Silurian? and Devonian), though it is probable that some of the clay-slates, &c. in the chain of the Chilian Andes, to which he adverts, are of older age.

† Roemer: Texas, und die physischen, &c. 1849.

‡ See Cordier, 'Rapport à l'Académie Royale des Sciences sur les résultats scientifiques du Voyage de M. Alcide d'Orbigny dans l'Amérique du sud, pendant les 8 années depuis 1826 jusqu'à 1833.' 1842.

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gneiss, with intermingled quartz rocks, micaceous and chloritic schists, and highly crystalline limestone; the whole having been subjected to infinite folds.

This great fundamental group, bearing the name, according to Logan, of the Laurentian System, and on which all the other sedimentary deposits repose, extends westward to the Lakes Winnipeg and Superior, and, crossing the St. Lawrence at the Thousand Islands, reappears in the mountains of Adirondack, in the State of New York. It stands, therefore, like the oldest gneiss of the north-western coast of Scotland (see diagram, p. 199), as the oldest visible rock of the western continent. Like the venerable Scottish gneiss, it is also unconformably surmounted by hard sandstones, conglomerates, and schists (with some chert and limestone), which, attaining the vertical dimensions of about 12,000 feet on the north shore of Lake Huron, have been termed "Huronian." This Huronian group or system, which has been paralleled by Logan with the Cambrian or Longmynd rocks of Britain, is again covered transgressively (as in our north-western Highlands) by the lowest of the fossiliferous bands of the Lower Silurian or Potsdam sandstone (c^1 of Section, p. 199).

For the present we may leave the consideration of those other crystalline rocks which form a broad and long zone, ranging from S.S.W. to N.N.E., along the seaboard of the United States, and extend into Canada and the British colonies of Nova Scotia, Newfoundland, and New Brunswick. Now, although in the geological maps of North America* these rocks have been hitherto laid down under the same colour as those of the Laurentian system, they are essentially distinct from the old gneiss and its associates, and are, as will presently be shown (at least in several parts), nothing more than highly metamorphosed Silurian strata; thus affording another analogy to the rock-masses of the north-western Highlands of Scotland already described (pp. 180, 195 *et seq.*).

It is on the western flank of the Appalachian chain, and to the south, north, and west of the Laurentine Mountains, that the paleozoic formations are best exhibited. They consist of Lower and Upper Silurian, Devonian, and Carboniferous rocks, and are repeated in broad undulations, forming basins of a grandeur and extent unknown, as yet, in any other part of the world excepting Russia. In this way, they occupy large portions of the southern and western States of Alabama, Tennessee, Arkansas, Missouri, Illinois, Indiana, &c., as well as the newly-settled territories of Iowa, Minnesota, and Wisconsin. Such deposits range, too, along the southern side of the great chain of lakes, and are spread

* The maps of Lyell, Marcou, and others, which have represented these eastern crystalline stratified rocks, with their various intrusive or igneous rocks, whether granite, porphyry, or greenstone, &c., under the same primary colour as the Laurentine Mountains, must now undergo some modification. The statement made in the first edition of this work (p. 410) is therefore incorrect.

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over extensive tracts of New York, Pennsylvania, Maryland, and Virginia, where their stratigraphical features have been elaborately worked out, and their organic remains described, by American geologists.

These native authorities have honoured my labours by including the lowest of these great masses of fossiliferous rocks in the Silurian system; whilst all my contemporaries* who have gone from Europe to explore the United States, or the adjacent territories, have recognized Silurian rocks, both Lower and Upper, followed by deposits of Devonian and Carboniferous age†. In the Canadas, where Bigsby and others were his precursors, Logan, the Director of the Geological Survey of that great colony, has mapped enormous tracts both of Lower and Upper Silurian rocks; whilst Richardson, triumphing over all the obstacles of the inclement North, has followed Silurian limestones along the western flank of the granitic chain from Lake Winnipeg to the mouth of the Mackenzie River. The latter has also shown to how great an extent these strata wrap round the huge crystalline nucleus of North America, and form the edges of the continent towards the Arctic Sea. In many of the Arctic islands, too, Upper Silurian fossils have been detected by the skilful navigators who have sailed in search of the lamented Franklin.

I shall cull, in the sequel, a few data from some of these British authorities; but let me first allude to those tracts which, through the labours of American geologists, have been rendered classical in our science, and where the types of comparison have been the most sedu-

* See Bigsby, Trans. Geol. Soc. Lond. 2 ser. vol. i., and Quart. Journ. Geol. Soc. vol. viii. p. 400; &c. Featherstonhaugh, Reports on the Countries between the Missouri and Red Rivers, and of Wisconsin, &c., Washington, 1835–6 [my old friend Mr. F. first made known to me the existence of the Silurian series in the United States]. Lyell, Travels in North America, with general map, 1841–42, London, 1843. Lyell's Geological Manual, 3rd ed. p. 351. Castelnau, Système Silurien de l'Amérique Septentrionale, Paris, 1843. De Verneuil, Bulletin de la Société Géologique de France, 2nd ser. vol. iv. Paris, 1847. Richardson, Narrative of an Arctic Searching Expedition, 2 vols., London, 1851. Logan, Geological Survey of Canada; Reports to Legislative Assembly, and maps. Logan with Salter on the Rocks of Lower Canada, Brit. Assoc. Reports, 1852, p. 59; Quart. Journ. Geol. Soc. Lond. vol. ix. Ferdinand Roemer, Texas und die physischen Verhältnisse des Landes, Bonn, 1849, with geological map. Desor, Bull. Soc. Géol. Fr. 2 ser. vol. ix. p. 342; and, lastly, M. Jules Marcou, Geological Map and Description of the United States and British North America, Boston, 1853. The last-mentioned author has dedicated this work to his friend Agassiz, who has thrown so much new light on the natural history of his adopted country. This book and map, embracing the new surveys of Dale Owen, Logan, and others, contains also a list of all writers on American geology.

† It was my anxious desire to have visited the United States and the Canadas last summer, when illness prevented the enjoyment and instruction I had promised myself. As, however, my place was taken by my associate Ramsay, whose acquaintance with the British paleozoic rocks is as extensive as it is accurate, I am fortunately enabled, through his communications, not only to correct several errata in the first edition, but to bring the older formations of America into a much more accurate parallel with our own deposits than could otherwise have been attempted. This will be specially shown in a tabular comparison between the Silurian and Devonian rocks of America and Britain, which Professor Ramsay has prepared for me as the result of his excursion, and of his intercourse with Mr. J. Hall, Sir W. Logan, and other geologists. This table is given at page 472.

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lously and accurately described*. The State of New York, for example, presents a noble series of paleozoic deposits, as laid open on the banks of many rivers. By the examination of these natural sections, the geologists of that State have been enabled to describe a detailed order, which is remarkable for its symmetry and unbroken condition from the base of the Lower Silurian to the coal-measures included; the whole being generally arranged in slightly inclined and conformable strata.

The local subdivisions (about eighteen in number, and of very unequal dimensions) of which the Silurian system, so admirably described by Mr. James Hall, is composed in the State of New York, are compared with their European equivalents in a Table which follows (p. 472). Independent, however, of these numerous subdivisions, the lower portion of the series has been admitted by American authorities to be divisible, as in Europe, into two groups, each characterized by peculiar fossils. Thus, from the "Potsdam Sandstone," or base of the whole fossiliferous series, up to the slates and arenaceous schists of the Hudson River group, overlying the Trenton limestone, the mass so composed represents the Lower Silurian. In this view, de Verneuil, Logan, Bigsby, Ramsay, Salter, and others†, agree with the United States' geologists.

In the lowest of these deposits, at Potsdam, a small Lingula (L. antiqua, Hall) was, for a long time, the only fossil known except fucoids and abundant traces of marine worms (Scolithus linearis). Similar vertical annelide burrows have been mentioned (p. 41) as occurring in the Stiper Stones of my first typical Silurian tract (1833), and are equally common in the quartz rock of Durness, in Sutherland, which underlies the limestone with American types of mollusca (see pp. 180, 195 *et seq.*, 217, 222). The parallel, therefore, between these British and Transatlantic zones seems to be complete.

Footprints of a large animal were discovered in rocks of a similar age in Upper Canada, on the north bank of Lake Ontario. In the first instance, they were supposed to have been made by the feet of a chelonian reptile. But a further examination of numerous casts taken from the footmarks, and brought to England by the zeal of their discoverer Logan, led Professor Owen to refer them to crustaceans,—the class of animals which is most commonly met with

* My contemporaries in America, whose labours I highly estimate, will readily understand that in a work which is limited to the general history of the paleozoic rocks, and specially those of Europe, I have no space to render justice to the numerous able writings which treat of those tracts of the United States or the British Colonies, where such paleozoic rocks are little developed. Thus, the works of Hitchcock, whose description of the structure of his native State, Massachusetts, and the accompanying map, are models of geological monography,—of Dana, whose insight into the natural history of zoophytes, and whose philosophic reflections on the outlines of the earth, have secured for him a wide reputation,—and the various contributions to the excellent volumes of my friend Professor Silliman,—must now be passed over; although, if general geology were my object, they would be eagerly appealed to. Nor will the reader find in the text any allusion to the labours of some authors who have been highly useful in building up the now well-established series of the older formations; such as Maclure, Eaton, Troost, Emmons, Perceval, Vanuxem, Conrad, Jackson, Foster, Dawson, Thompson, Whitney, and others. The few works above referred to are necessarily those in which the authors have dilated on the subjects which are specially treated of in this volume, *i. e.* comparative views of paleozoic geology.

† Lyell took the same view in his 'Travels in America,' and also in the early editions of his 'Manual of Geology.'

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in rocks of Silurian age. This view being now adopted, we have evidence of a great protozoic crustacean, probably not unlike the giant Pterygotus described in an earlier chapter (p. 155). The Lower Silurian fossil, Cruziana, so well known in Britain, France, and Spain, also occurs in this lowest zone.

The most marked mineral distinction between the rocks which immediately lie upon this true Silurian base, as compared with those of like age in Britain, is the much greater prevalence of limestone. A calcareous sandstone, called the "calciferous sand-rock," which has been paralleled with the crystalline limestone of Sutherlandshire (pp. 196, 217, 222), is succeeded by the Chazy limestone, Bird's-eye, and Black River limestones, and they are at once followed by the great Trenton limestone with its overlying schists (Utica slate and the Hudson River group). In the lowest of the calcareous masses—the Chazy limestone, the peculiar molluscous genus Maclurea (see the figure, p. 215) is found, together with some Corals, Bryozoa, and a few trilobites (Illænus, Asaphus, &c.).

The succeeding calcareous beds—Bird's-eye* and Black River limestones, forming the base of the Trenton limestone, seem to stand in the place of the Llandeilo of Britain, though, as will be shown in the Table, they enclose a larger and more mixed suite of Lower Silurian fossils with some Caradoc forms. They contain many enormous Orthocerata, the singular cephalopod genus Gonioceras of Hall, large Lituites, and several univalve shells (Murchisonia, Scalites, &c.), besides many species of Orthis and Leptæna, including Leptæna sericea, with other brachiopods.

The rock into which these beds pass, or the Trenton limestone, is chiefly, as regards its fossils, a fuller development of the last-mentioned deposits; the number of trilobites, gasteropods, brachiopods, and crinoids being vastly increased. Besides the large Asaphus (Isotelus) gigas, the characteristic fossil of the stratum, Trinucleus concentricus occurs, with the genera Cheirurus (Ceraurus of Green), Lichas, Phacops, and Calymene, all of different species to those of England. But among the shells, Orthis striatula, O. biforata or lynx, O. porcata (occidentalis, Hall) (Foss. 33. p. 210), and Bellerophon bilobatus (Pl. 7. f. 9), are Lower Silurian fossils, characteristic of the same rocks in Britain, Scandinavia, and Russia. The geological position of this limestone is maintained, too, by the presence of numerous species of Lituites, Orthocerata, and large plaited Orthides, which resemble those of Europe, without being identical. Such, for example, are the two large-plaited species, Orthis tricenaria and O. pectinella, which represent the British forms, O. Actoniæ and O. flabellulum (Foss. 32. p. 209), and yet are perfectly distinct.

The Trenton limestone is overlaid, throughout a considerable tract in North America, by the Hudson River group, at the base of which lie the Utica slates, full of their characteristic graptolites. These are covered by, and often pass into, schist and sandstone, also containing many Graptolites with other fossils; the last-mentioned beds being now considered the equivalents of the Caradoc or Bala formation†.

* So called from the numerous specimens of Phytopsis cellulosa which stud the beds and look like eyes.

† M. de Verneuil was the first European geologist who, having examined the collections and visited the localities of the American fossils, successfully compared them with those of our continent. See his most instructive memoir, Bull. Soc. Géol. Fr. 2 ser. vol. iv. p. 646. The Lower Silurian had not then been subdivided as it now is (see Table, p. 472).

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The conglomerates and sandstones of Oneida and Medina which succeed are, it is believed, the representatives of the Lower Llandovery rocks of Britain, and, like them, they may, according to my view, be classed as the uppermost part of the Lower Silurian rocks. Though containing few fossils in the continent of America, beds occupying the same position in the large island of Anticosti, at the mouth of the St. Lawrence, are charged with shells, which have led Sir W. Logan to refer them also to this date*. Besides Pentameri, they there contain the following Silurian types, viz. Leptæna sericea, Orthis striatula, and Strophomena alternata, with the remarkable fossil Beatricea, so named by Billings, at first supposed to be the stem of a tree-fern; but the appearance of vegetable structure has been ascertained by Dr. Hooker to be deceptive, and is due to crystallization†.

According to Hall, Logan, and most American authors, as well as Dr. Bigsby, the "Clinton group" has been considered the base of the upper division in the United States. It is characterized by the typical Pentamerus oblongus, which, as in England, is never found in any of the succeeding strata.

The same authorities, as Professor Ramsay informs me, now group these rocks, containing Pentamerus oblongus, and their inferior sandstones as "Middle Silurian"; for, like the Llandovery rocks, they essentially occupy the central part of this natural system. For general purposes of classification, I prefer, however, to adhere to the simple terminology of Lower and Upper Silurian; grouping the Lower Llandovery rocks with the former, and the Upper Llandovery with the latter division (see Chapter V.).

This method is, it seems to me, preferable, because this central group, which unites, by its fossils, the inferior and superior masses, is in Europe by no means rich in organic remains, and, in some countries, cannot be easily separated from the subjacent and overlying deposits.

The Clinton group is immediately followed by the Niagara shales, which in all respects resemble the well-known Wenlock shale of Britain; whilst the chief or central mass of the Upper Silurian rocks in North America is that called the Niagara limestone, which unquestionably represents the Wenlock and Dudley limestones of England, as well as of Gothland in the Baltic. These rocks appear to contain a greater number of fossils identical with those of Europe, than do the Lower Silurian strata of the same districts. Among them are Calymene Blumenbachii, Homalonotus delphinocephalus, Bumastus Barriensis, Rhynchonella cuneata, R. Wilsoni, Pentamerus galeatus, Orthis elegantula, O. hybrida, Ortho-

* See Geological Survey of Canada, Report of Progress 1853 to 1856 inclusive, Toronto, 1857, p. 248. This volume, with its accompanying illustrations and book of maps and plans, is highly instructive, and does infinite credit to the Canadian Survey, both as respects the additions to our acquaintance with the physical geography and geology of large tracts never before mapped, as divided by Sir W. Logan, and executed by Mr. Alex. Murray; the report on the wild and unexplored large island of Anticosti by Mr. James Richardson; the descriptions of the Canadian fossils by Mr. E. Billings; and the reports on the minerals and mineral waters of the region by Mr. T. Sterry Hunt. Sir W. Logan and his associates divide the Lower Silurian into seven deposits, viz. Potsdam sandstone, Calciferous sand-rock, Chazy limestone, Bird's-eye and Black River limestones, Trenton limestone, Utica slate, Hudson River group. Then follows the Anticosti or Middle Silurian group, succeeded by Upper Silurian, Devonian, and Carboniferous (Report, p. 248).

† Mr. Salter believes that the Beatricea, though thirty feet long, may be a gigantic annelide tube, allied to Cornulites. Its cellular structure leads him to this view. Amphitrite has a thick shelly tube some feet in length.

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ceras annulatum, Eucalyptocrinus decorus, and Bellerophon dilatatus. (See Chaps. 9 and 10.) Some of the large European corals also prevail,—those which may have been capable of forming reefs, as Favosites Gothlandicus, F. alveolaris, and the chain-coral. There are also many peculiar species: indeed, Professor Milne-Edwards has shown, that out of a considerable list of American corals, few are really identical with those of Europe.

The lower formations of the next overlying or Helderberg division, up to the higher Pentamerus limestone inclusive*, constitute (according to de Verneuil) the probable equivalents of the Ludlow rocks. The much greater abundance of calcareous matter in the higher part of this division than exists in our own Ludlow rocks, and the absence of that muddy and sandy matrix which characterizes those strata in Britain, have necessarily given to the whole group more the character of the Wenlock formation,—a feature which, as we have already seen, is dominant in Gothland, Russia, Bohemia, &c.

Devonian Rocks.—The base of the Devonian rocks of the United States has recently been placed lower than it was in the earlier comparisons with European deposits. Seeing that a mass of sandstones and conglomerates had there been called "Old Red Sandstone," it was natural, in the first instance, for geologists to suppose, that the Devonian series in North America did not descend far beneath this rock. But Hall and others have long since agreed with de Verneuil in considering the Oriskany sandstone to be the true Devonian base; for this rock contains Spirifer macropterus, Pterinæa fasciculata, and Pleurodictyum problematicum, all species of the lowest Devonian of the Rhine, Belgium, and France, which are unknown in any Silurian rock (see Table, p. 433). The lowest Devonian rock in America is, therefore, precisely similar to its type in Western Europe.

A further reason for placing the Oriskany sandstone at the base of the Devonian rocks of New York consists in the clear indications of its having been deposited in excavations of the inferior stratum, as explained by Mr. J. Hall. This phenomenon marks a previous denudation, and the commencement of a new series†.

* These consist in ascending order of the Onondaga Salt group, the Water-Lime group, Pentamerus limestone, Delthyris shaly limestone, Encrinal, and Upper Pentamerus limestone.

† Recently the subject of the succession of the North American deposits, whether in the State of New York or in the adjacent British territories, has been clearly illustrated by Dr. Bigsby, one of the most able and energetic explorers of those regions in former years. The general succession is that given in the Table at the end of the chapter. Dividing the Silurian rocks into Lower, Middle, and Upper, Dr. Bigsby makes also a triple division of the Transatlantic Devonian rocks analogous to that of Europe. In addition to many important inferences respecting the distribution of paleozoic life, Dr. Bigsby infers that "the Silurian and Devonian systems of New York belong to one connected period; being the products of successive and varying Neptunian agencies, operating in waters which deepened westward from the Atlantic side, and southward from the Laurentine chain on the north. These paleozoic groups pass one into the other by gradual mineral and zoological changes; there being a nearly perfect conformability and a considerable community of fossils. The chief break is at the Oriskany sandstone (base of the Devonian), there being no break of like importance at the period of the local Oneida conglomerate (Middle Silurian). A division of the Silurian and Devonian systems, each into three stages, is based on the change of sediment and on the fossil contents. The Middle Silurian stage is a period of especial transition; from the coarseness of some of its sediments, and from their alternations, as well as from the organic poverty prevailing." (See the abstract of his memoir in the Proceedings of the Geological Society of London, No. 5, Session 1857–8.)

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Judging also from the included organic remains, such as Goniatites, identical with those of the duchy of Nassau in Germany, Murchisonia bilineata, Productus subaculeatus, Athyris concentrica, and other fossils, M. de Verneuil further included in this group the Chemung rocks, the Hamilton and Marcellus shales, and the Cliff limestone of Ohio and Indiana (Corniferous and Onondaga limestones). The last-mentioned deposits contain fossil fishes analogous to those of Scotland, besides some characteristic Devonian shells. Again, the occurrence of an ichthyolite of the genus Asterolepis, associated with forms of Spirifer, in the Schoharie grit of New York, necessarily placed that rock also in the Devonian series.

As fossil fishes have usually proved the most exact indicators of the age of rocks, the occurrence, in these Devonian strata, of Asterolepis, a genus common in the central Scottish beds of this epoch, and the intermixture of other ichthyolites, identical with those of the same country, with shells of the Eifel and of Devonshire, are to me the most convincing proofs that these diversified deposits in North America (like those of Russia, the Rhenish provinces, and Devonshire) are simply equivalents, in time, of the very grand British deposits called Old Red Sandstone. For, it must be recollected, that under this term, and particularly in the north-east of Scotland, are included conglomerates, sandstones, grey schists, limestones, and flagstones, as well as sandstones of both red and whitish-yellow colours; in all, many thousand feet thick. (See pp. 270, 280 *et seq.*)

In one portion of the Canadas, Mr. Logan has estimated the Devonian rocks to have a thickness of 7000 feet; and in the State of New York they occupy a more considerable space than the Silurian. But this Devonian series of micaceous sandstones and schists thins out, as it passes westwards into the States of Ohio, Indiana, and Kentucky, and disappears entirely on the Mississippi, where the Carboniferous strata repose at once on those of Silurian age.

Carboniferous Rocks.—The Carboniferous rocks are, as is now well known, developed in the United States, in basins of vaster dimensions than in any part of Europe. By aid of their included fauna and flora, the American strata are absolutely identified with the deposits of like age in Europe. Great masses of sandstone and schists, once considered to be Devonian, and so coloured in early geological maps of the United States, have been shown by M. de Verneuil to be, from their imbedded fossils, of Carboniferous age. These masses, which are of considerable thickness, form the true base of the carboniferous rocks of North America, and are probably the equivalents of much of the yellow sandstone of Ireland, as well as of certain rocks in Westphalia, which were formerly classed with the "Grauwacke," but are now ascertained to belong to the inferior carboniferous beds of the Rhenish provinces. (See p. 427.)

Next follows the Carboniferous limestone (Mountain limestone of early English geologists), which, whilst it encircles the great coal-fields of Michigan, Illinois, and the southern part of the Appalachian coal-field, is wanting in Pennsylvania and Ohio. This rock contains many varieties of Productus; viz. P. semireticulatus, P. Cora, P. punctatus, &c., with species of Bellerophon, Goniatites, Spirifer, and Terebratula, known not only in Britain, but also in many parts of Europe and Asia*.

* The cestracion fishes of Illinois, discovered by Dr. B. Shumard, have been described by Dr. Joseph Leidy (Trans. Amer. Phil. Soc. vol. xi. p. 687).

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The Foraminifera, a group of which few traces occur in the lower paleozoic strata, have also a very wide range; for the very same species (Fusulina cylindrica), which so abounds in Southern Russia, is also found in the carboniferous rocks of N. America.

The lamelliferous corals (Zaphrentis, Lithostrotion, &c.) are not absent; but they are chiefly of species distinct from those of Europe; and some of the forms of this group most characteristic of the old continent (Syringopora, Amplexus, &c.) appear to be absent from this series in the new.

It is unnecessary here to dilate upon the vast overlying productive coal-fields, which, occupying distinct basins of stupendous dimensions, have been described by numerous native authors, and have been well depicted by Lyell and Dawson. But I must advert to the great similarity—nay, identity—between the plants of these vast coal deposits and those of Europe. It is a feature highly worthy of the special notice of geologists, that at this early period the same species of gigantic plants were spread over an enormous area of the earth's surface, which, from the nature of its vegetation, must, therefore, have been under the same conditions of atmosphere and climate, if not of physical outline. This specific agreement is indeed curiously at variance with the sharp distinction between the existing floras of N. America and Europe. (See Lyell's Travels in N. America, first edition.)

This short notice of the development of the earlier fossiliferous rocks in the United States cannot be concluded without a special allusion to the important additions made to this branch of knowledge by certain American authors. The researches of Mr. James Hall, as recorded in his work on the Paleontology of the State of New York*, have shown that, with increased observation, the difficulty is great (except for short distances and in limited tracts) in drawing an arbitrary line between the lower and upper divisions of the Silurian system. The thinning out or thickening of the subdivisions termed Medina sandstone, and the Clinton and Niagara groups, are accompanied by just the same kind of intermingling of fossils which has been observed, though to a greater extent, in the British Isles. Several species, says Mr. Hall, known before only in the lower are now found at the base of the higher group. But, before we can speak of the number of species which range from the Lower into the Upper Silurian, all the older fossils of North America must be examined and compared. Even, however, in the one State of New York we learn, that Bellerophon bilobatus, Orthis lynx, Strophomena (Leptæna) alternata, and some other forms common to Europe and America, and abundant in the Lower Silurian, occur in the higher part of the Medina sandstone, which in that country is intimately united with the upper division.

The same elaborate work of Mr. Hall must be consulted for the figures of many species of fucoids common to the Medina sandstone last noticed, and the associated Clinton group. Numerous tracks or trails of gasteropods and crustacea also occur, indicating that the sediment so marked was accumulated in shallow water, or under ebbing and flowing tides, and on sloping shores. To the consideration of these data we shall return in the last chapter, in explaining the conditions under which some of the oldest marine deposits were formed.

Notice must also here be taken of the survey of the extensive territories of Wisconsin, Iowa, and Minnesota, by which Dr. Dale Owen has extended

* Nat. Hist. New York, part vi. Paleontol. vol. ii. 1852, p. 3.

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true paleozoic classification on a very broad scale. The area examined by this author and his associates, Drs. Norwood and Shumard, is much larger than Great Britain; and by far the greater portion of its subsoil is referred by them to the Silurian, Devonian, and Carboniferous rocks*. This magnificent region is traversed by the Mississippi in its descent from the boundaries of British America and Lake Superior, and is included between that mighty river and its huge affluent the Missouri. Surrounding and supporting an enormous carboniferous tract, the older primeval rocks rise out successively in very slightly inclined positions. The results of this survey which have most interested me are the discovery of two bands containing trilobites, in the lowest Silurian sandstone, and the fact that the organic forms of these beds are considered to be referable to the primordial Silurian zone (Barrande), such as it exists in Bohemia and Scandinavia, or in the "Lingula flags" of Britain. (See pp. 42, 369, 394.) We thus obtain proofs, that the earliest fossiliferous deposit of America, whether in the condition of sandstone at Potsdam, and in the western region of the Mississippi, or as the metamorphic and slaty rocks of the eastern seaboard of the United States, does really contain, as in Europe, the first clearly recognizable fossil animals which pertain to the series of Silurian life†.

Recently, indeed, specimens of a very large species of true Paradoxides have been found by Professor W. Rogers in a band of siliceous and argillaceous slate, ten miles to the south of Boston, which is enclosed between great masses of igneous rocks. Learning from Professor Ramsay that he has seen other proofs that these eastern crystalline rocks are of Lower Silurian age, as pointed out to him by J. Hall, I venture to suggest that much of the crystalline masses which flank the coal-fields of the British Colonies of New Brunswick, Nova Scotia, &c., may also prove to be metamorphosed Silurian strata. Such a result will greatly extend the structural analogy already shown to exist between North America and the Highlands of Scotland.

The Lower Silurian, so termed and laid down on their map by Dale Owen and his associates, consists, in its inferior portion, of pebble-beds, grits, and sandstone‡ of red and greenish colours, which, as they range upwards, begin to alternate with magnesian limestone. Then, in ascending order, the limestones with green grains (resembling some of the Russian Lower Silurian, p. 374) predominate, and are in parts oolitic, in other parts quartzose and cherty. Again, sandstones, usually white, recur, and are surmounted by shelly beds, which, in Iowa and Wisconsin, represent the Trenton limestone of New York, or the Llandeilo formation of Britain.

* This work, following so many other valuable publications, is a proof that the Senate, as well as the State governments, have justly appreciated the value of the application of geological science as a prelude to the settlement of a new country.

† See 'Proofs of the Protozoic age of some of the altered rocks of Eastern Massachusetts,' by Professor W. B. Rogers, Proc. American Academy of Arts and Sciences, vol. iii. 1856; and Proc. Boston Nat. Hist. Soc. vol. vi. pp. 27, 40, &c.

‡ The Trilobites of this, the lowest fossiliferous stratum in America (the Potsdam sandstone), are termed by Dr. Owen, Dikelocephalus, Lonchocephalus, &c. Judging from the drawings, these genera seem to be referable to the same group as Paradoxides. They are associated with Fucoids and Linguleæ. After studying the work of Dr. Dale Owen, M. Barrande is convinced, that the author has established in the New World the proof of the existence of the primordial Silurian zone of Bohemia and Sweden, and the same order of succession upwards from it into the mass of the Silurian strata, as in Europe. In this view de Verneuil coincides.

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The Upper Silurian rocks are poorly represented, in these unfrequented tracts, by what Dr. Dale Owen terms the Upper Magnesian Limestone, consisting of beds with corals and Pentameri; all traces of the equivalents of the Ludlow rocks being absent. The Devonian period is, however, clearly defined, particularly by its broad-winged Spirifers; whilst the carboniferous limestone is so expanded, as to be distinctly referred to the Yoredale series, of Phillips, in Yorkshire. The western explorations of Captain Stansbury to the Mormon territory and the Salt Lake of Utah, to which an allusion was made in the first chapter, have further shown us, that strata charged with Carboniferous fossils extend to the edge of the Rocky Mountains, those great northern extensions of the Andes.

Silurian and other Paleozoic Rocks of British North America and the Arctic Regions.—Old sedimentary rocks, similar to those of the United States, range, as before partially stated, into the British provinces of North America, where, after a long and able survey, Sir William Logan has shown that they generally follow the same symmetrical order as in the contiguous countries of the United States. They have, also, in their eastern division, been thrown into the same contorted and occasionally inverted order, as had been indicated by the Professors H. and W. Rogers, along this line, in more southern latitudes. In the opinion of the last-named geologists, the causes of the rapid curvatures and partial inversions, by which younger strata have been so folded as to pass under beds previously formed, were violent earthquakes, the greatest intensity of which was exhibited where the folds are most rapid and numerous. As the intensity of the shock diminished, the strata are supposed to have rolled on in broad and regular undulations, thus resembling the waves of the sea at a distance from the area of strongest vibration. Although I can here but simply advert to this ingenious explanation, it is satisfactory to me, as an historian of the older geological series, to find that, by whatever agency such grand contortions were produced, these inverted strata of North America, like those of Europe already spoken of (pp. 430, &c.), can be followed, until they fold out from their overturned positions and regain their natural order. This is shown by the uppermost of the two sections at p. 467, which serve to explain the general relations of the paleozoic rocks in N. America.

In one portion, however, of Lower Canada, as Sir William Logan assures us, just as in the west of the United States, all the paleozoic rocks, from the Potsdam sandstone or Silurian base upwards, as in Scandinavia and Russia (Chapter 14), are strictly conformable. The only great break in that territory, *i. e.* along the Lake Huron, is between the Potsdam or lowest fossiliferous rock and the great *un*fossiliferous and inferior mass, the Huronian, which consists of bluish schist with sandstones, chert, and limestones, estimated to be about 12,000 feet thick. These, again, are seen to have been unconformably deposited on still older rocks, consisting of micaceous and chloritic schists, with bands of crystalline limestone and quartz rock (Laurentian), gneiss, and granitic rocks*.

* Sir William Logan, who has laid down a most elaborate and valuable geological map of the Canadas, has pointed out some of the chief incidents in the geology of these regions in his Reports of Progress to the Provincial Government (see p. 460). He has also published a succinct view of the whole ascending order in Upper Canada. There, the Lowest Silurian rock does not repose at once on gneiss and granite, as in the above section across Lower Canada, but is separated from such rocks by the unfossiliferous or bottom slaty rocks above noted. In the same memoir Mr. Salter confirmed the views

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The oldest of these masses (now called Laurentian) have connexion with those rocks only which have been spoken of in the first chapter of this work and at pp. 21, 199, and 365; but the next in ascending order, the Huronian, or the copper-slates and sandstones of the great lakes, have, to some extent, the same structure as considerable portions of the Longmynd or "bottom rocks" of the Silurian region. They are, in truth, defined as such by Logan, being termed by him the equivalents of the Cambrian of De la Beche, Ramsay, and the British Government Surveyors. In England and North Wales these old slaty rocks contain no limestone, but, in North America, lime is interlaced with them.

Again, whilst in Great Britain and Germany these Cambrian rocks are succeeded conformably by the Lower Silurian, they have been severed therefrom in America, as in France and Ireland, by a grand dislocation. In thus appealing to the conditions in different countries, we learn the impracticability of classifying sedimentary deposits by the lines of fracture and dismemberment alone. But, in stating these facts, I beg not to prejudge the question, so ingeniously developed by my eminent friend, M. Elie de Beaumont, concerning the parallel and discordant directions of mountain-chains, as typical of certain epochs. The discussion of this topic would require many chapters, and lead me away from the special objects of this work.

In Nova Scotia the older paleozoic rocks have not been traced, though probably, as before said, some of the crystalline rocks may prove to be of Silurian age; but the productive coal formation is there magnificently displayed*.

In taking a general view of the physical structure of the northernmost portion of America, Richardson, the great Arctic traveller, considers that, on the whole, the granitic and crystalline rocks of the central and eastern countries of the Hudson's Bay territories (the Laurentian) are surmounted by few other deposits on the west and north, except by masses of Silurian age, and very young tertiary strata. In his graphic description of the structure of Canada, Lyell expresses the same opinion. "I seemed," says he, "to have got back to Norway and Sweden, where, as in Canada, gneiss and mica schist, and occasionally granite, prevail over wide areas, while the fossiliferous rocks belong either to the most ancient or to the very newest—to the Silurian, or to deposits so modern as to contain exclusively shells of recent species†." From the western shore of Lake Winnipeg, a limestone with gigantic Orthocerata (allied to those described by Dr. Bigsby and Mr. Stokes‡, from the Upper Silurian of Drummond Island), and the strange fossil Receptaculites§, was traced in horizontal sheets stretching westwards over four

of Sir W. Logan with regard to the age of the strata in Lower Canada, and identified many fossils as equivalents of the New York series. See Report Brit. Assoc. 1851, Sect. p. 59, and also Quart. Geol. Journ. vol. viii. p. 199. It is well here to observe, that in some parts of Canada, however, as on the Ottawa River, the minute subdivisions of the Lower Silurians of the New York territory are no longer traceable. There, one limestone of vast thickness contains within it the fossils of the Bird's-eye, Black River, and the Trenton group. Even the lowest limestone, the Chazy, is represented in this calcareous mass; for though the great Maclurea magna of the Chazy limestone is not present, a large and fine species, the M. Logani, takes its place. See Rep. Brit. Assoc. 1851, Trans. Sect. p. 63.

* For full descriptions of these rocks, I must refer the reader to memoirs in the Journal of the Geological Society, by Sir Charles Lyell, Mr. Dawson, and Sir W. Logan.

† Travels in N. America, 1st series, ed. 1, vol. ii. p. 124.

‡ Bigsby and Stokes, Geol. Tr. 2nd ser. vol. i. Similar Orthoceratites were found by Sir W. Logan further to the east, in rocks of Upper Silurian age.

§ Now referred by Mr. Salter to the Foraminifera, as a gigantic form allied

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IDEAL SECTION ACROSS THE APPALACHIAN CHAIN.

By Professor H. Rogers.

N.W. S.E.

N. GENERAL SECTION ACROSS THE OLDER ROCKS OF LOWER CANADA NEAR THE MOUTH OF THE ST. LAWRENCE. S.

By Sir W. Logan.

gn. Gneiss, &c.
t. Trap dykes.
a. Lower Silurian (consisting, in Canada, of Potsdam sandstone, Calciferous sand-rock, Trenton limestone, Utica slate, and Hudson River group). *a**. Altered Lower Silurian. *b*. Upper Silurian (in Canada, Gaspé limestone, &c.). *c*. Devonian. d^1. Lower Carboniferous rocks and sands. d^2. Coal-fields.

The lower diagram was drawn, six years ago, by Sir William Logan, to show how, in the eastern portion of Canada, the ancient crystalline rocks, *gn*, now termed Laurentian, are unconformably overlapped (the Huronian or Cambrian rocks being omitted in this tract) by Lower Silurian rocks, *a*, consisting of Potsdam sandstone, Calciferous sand-rock, Trenton limestone, Utica slates, and the Hudson River group. The superior rocks (Upper Silurian, Devonian, and Lower Carboniferous, *b*, *c*, *d*) succeed. The strata have been much contorted, as in the eastern region of the United States. See also Logan, Quart. Journ. Geol. Soc. vol. viii. pp. 203, 206.

The upper diagram is reduced from one of the numerous instructive sections by the Professors Rogers, and, although called ideal, is based on facts observed in crossing the Appalachian chain, in the parallel of Pennsylvania. The oldest stratified rock on the S.E. of that section, which in the first edition (following American authorities) was termed gneiss, &c., is now known to be metamorphosed Lower Silurian, *a**. These rocks range along the seaboard of the continent, and, extending northwards into the States of Vermont, Maine, and Massachusetts, probably occupy large portions of the British colonies of Nova Scotia and Newfoundland. In traversing the Appalachian chain to the west, the Lower Silurian rocks are succeeded by the Upper Silurian, *b*, having the Niagara limestone as its great mass, which, supporting the Devonian rocks, *c*, in a partially inverted basin, are followed by the last oblique axis. Further to the north-west, each anticlinal and synclinal arrangement gradually assumes its *vertical* and normal relations, the folds become broader, until the Devonian rocks, *c*, are seen supporting regular carboniferous basins of shale, limestone, and coal, d^1, d^2, which, further to the north-west than is here represented, open out into the vast coal regions before adverted to.

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or five degrees of longitude. Though this plateau is separated from the Rocky Mountains by a broad belt of the prairies of the Saskatchewan, the bed of that river is full of limestone blocks which indicate the persistence of the rock. After crossing Methy Portage, in lat. 56¼°, Richardson again met with extensive calcareous deposits. The fossils which were gathered from this tract (Productus, Orthis, Spirifer, &c.) seem, however, to indicate an ascending order into beds of Devonian and Carboniferous age*, particularly in the wide spread of calcareous matter along the Elk and Slave rivers, and upon the banks of the Mackenzie. Where the last-mentioned river skirts the Rocky Mountains, the limestones, more disturbed than in the Winnipeg basin, occupy, says Richardson, inclined and elevated ridges, the chief of which he considers to be Silurian;—these ridges, on the Great Bear Lake and the Coppermine River, abut against granite. In a letter to myself, he adds, "I believe the strata of sandstone and limestone on the north coast of America to be wholly Silurian, though fossils are scarce. Towards the mouth of the Coppermine River there are, besides, magnificent ranges of trap with ores of lead and copper, including much malachite."

To whatever extent it may be found possible to separate the Silurian rocks which range along the Rocky Mountains into a Lower and an Upper group, it would at least appear, from the specimens which have been collected by our naval explorers employed in the Arctic expeditions, that the great mass of the most northern rocks belongs to the Upper Silurian group. This is certainly the case, if we judge from the collections made during the voyages of Parry, Franklin, Ross, Back, Austin, and Ommanney, and the private expeditions of Lady Franklin, particularly those of Penny and Inglefield, and the latest expedition under Sir E. Belcher. The fossils brought home by these commanders, and the officers and gentlemen accompanying them, have been examined and described† by Mr. Salter; and from his scrutiny it results, that the crustacea and mollusca are very similar to, and some of them identical with, those of Dudley or Gothland. Among these occur Encrinurus lævis, Angelin; Leperditia Balthica, His.; Pentamerus conchidium, Dalm.; Chonetes (Leptæna) lata? v. Buch; with Upper Silurian forms of Orthoceras, Murchisonia, Strophomena, Orthis, Rhynchonella, &c., besides Encrinites, and very numerous corals, including the chain-coral, the Favosites Gothlandicus, F. cristatus or polymorphus, and several other species characteristic of this division of the Silurian system, and, as might be expected, of American rather than European types.

The same inference has been drawn by the geologists who have surveyed the rocks, and the naturalists who have examined the fossils, of the northern edge of the great granitic region of the Laurentine Mountains. Their conclusion is, that, whilst on the south side a succession is seen from the crystalline strata into a copious and diversified Lower Silurian, as above explained, the northern side of the Hudson's Bay territory is chiefly occupied by Upper Silurian lime-

to Orbitolites, which is seldom found more than half an inch in diameter; but these older representatives of the order were not less than six or seven inches, and of a proportionate thickness!

* A few specimens of the fossils of these rocks are in the British Museum; they are Upper Silurian, Devonian, and Carboniferous. Unluckily numerous fossils brought home by Sir John Richardson in 1826 have been mislaid.

† Appendix to Sutherland's Journal of Capt. Penny's Voyage; 1850–51. London, 1852, vol. ii. with plates. See also Quart. Journ. Geol. Soc. vol. ix. p. 312, 1853.

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stones*. This inference is founded on the occurrence, at the base of the whole fossiliferous series in that district, of a profusion of corals, several of which are characteristic of the Niagara and Onondaga limestones (Wenlock or Dudley), together with the trilobite Encrinurus punctatus, the shells Atrypa reticularis and Pentamerus oblongus, with several other mollusca—Ormoceras, &c., indicative of the lower portion of the Upper Silurian group. Now, as in all the vast extent of land that has been surveyed in the Polar circle, no trace of an inferior Silurian formation has yet occurred, the inference seems justifiable that during that period the Polar land, indeed all the region north of the Laurentine dome, was raised above the water, and was subsequently depressed to receive successively the Upper Silurian, Devonian, Carboniferous†, and even some secondary deposits.

Looking, indeed, to that vast Arctic region, so little accessible to any man of science, the geologist has good reason to be thankful for the knowledge already obtained, which has enabled him to classify the older sedimentary rocks of icy regions, never trodden by civilized man before the present century.

In terminating this outline of the succession of the older fossiliferous rocks of America, let me remind the reader of the vast extent to which this continent is composed of Silurian, Devonian, and Carboniferous formations. In the Western hemisphere, as in Europe, the first clear signs of life are met with at the same low horizon in the crust of the earth; and similar great groups are clearly distinguishable. We also observe, that fishes, which, so far as clearly known, were called into existence only at the close of the Silurian period‡, and were of such peculiar forms in the Devonian epoch, become conspicuous in the Carboniferous deposits of America, and exhibit many new types, including the remarkable large sauroid fishes of Agassiz. Again, with a small amount of land vegetation in the Devonian, the Carboniferous rocks of America are characterized by the same abundant flora, and even by many species of the same shelly remains as in Europe, together with sauroid animals. The only essential difference, which was supposed to exist when the first edition of this work was published, between the older rocks of the two hemispheres was, that America offered no indica-

* Sir W. Logan has found that these limestones at the head of Lake Temiscamang include enormous blocks of the sandstone on which they rest; so that, in all probability, they are littoral deposits, and Pentamerus was not a deep-sea shell.

† The Permian rocks occur in Spitzbergen, but have not yet been observed in the Arctic regions of North America. Certain secondary limestones are charged with Ammonites and bones of Ichthyosauri in the most northern latitudes explored. See Belcher's 'Last of the Arctic Voyages,' vol. ii. pl. 35; M'Clintock, Journal of the Royal Dublin Society, Feb. 1857, p. 26; see also Rep. Brit. Assoc. 1855, Trans. Sect. p. 211.

‡ Reasons were adduced in the first edition, to show that the forms supposed to belong to fishes in the Niagara limestone and Clinton groups were probably parts of Crustaceans or of Annelida. We have as yet found them only in Upper Ludlow rock.

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tion of the upward termination of paleozoic life, which in Europe is marked by the Permian deposits. But even that distinction has been removed by the recent discovery of strata containing many true Permian species in the north-eastern part of Texas, and the same formation is now known to occur also along the eastern edge of the Rocky Mountains*; thus teaching us that all the seas of paleozoic times, even the very last of them, had a *quasi* universal extension, and were inhabited by similar groups of animals over enormously wide areas.

* The fossils which have brought out this coincidence between the youngest paleozoic rocks of the New and Old World, were discovered by Major F. Hawn and Dr. Cooper, and being sent by them to Mr. Meek of New York, that gentleman and Dr. Hayden have described some of them as belonging to Monotis, Myalina, Bakevellia, Leda (Nucula), Pleurophorus, Panopæa, Nautilus, &c. See Trans. Albany Institute, March 1858. These authors have no doubt that the shells are of the Permian age. Professor Swallow of Missouri, to whom another collection had been sent by Major Hawn, arrived at the same conclusion, and enumerates several species identical with European forms, also many corals. As these Permian fossils have already been procured from spots 100 miles distant from each other, and have been even traced to the northern border of Missouri, the strata in each case overlying the eroded surfaces of the carboniferous rocks, I agree with the suggestion of Mr. Meek and Dr. Hayden, that the formation will be found to have a considerable geographical extension in the far West.

In the first edition of this work, the geological structure of the Rocky Mountains was spoken of only as made known to us by the explorations of Captain Stansbury. The fossils collected by that officer and examined by Mr. James Hall proved to be Lower Carboniferous species, which occupied limestones overlying metamorphic schistose strata associated with granite. To this knowledge, M. Jules Marcou (now Professor of Geology at Zurich, and who had passed some months in the elevated region of the Rocky Mountains of Mexico) made the important addition of an upper carboniferous zone covered by a magnesian limestone, and followed by Triassic, Jurassic, Cretaceous, and Tertiary rocks. This view of the order of succession was communicated, indeed, as early as 1853 to the Geological Society of France; and, recurring to it in other works, and in his general map, published in succeeding years, M. Marcou has recently brought together all his observations in one volume. ('Geology of North America; with two Reports on the Provinces of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California, originally made for the United States Government.' April 1858, Zurich. See also Bibl. Univ. de Genève, Juin 1858.)

The magnesian limestone above the coal, of which this author has spoken, may fairly be considered of Permian age, if we judge from the fossils contained in strata occupying the same relative position in Kansas, discovered by Major Hawn. Dispersed specimens of the same fossils have, indeed, been found by MM. Meek and Hayden in the Black Hills on the eastern flank of the Rocky Mountains, near the northern affluents of the Platte river, in Lat. 53° to 54°, and W. Long. 104°.

This last-mentioned region, which is separated from that explored by M. Marcou by 9 degrees of latitude, appears to contain, besides the rocks described by that author, a band of Potsdam sandstone, or Lower Silurian rock, beneath the carboniferous deposits, as well as the overlying secondary and tertiary series of that author. These later deposits are not treated of in this volume. It will, however, be a subject of great interest to me, should the Permian zone be found to range northwards from Kansas and Mexico into the British territories. If my memory does not fail, certain small Producti, and other fossils in a magnesian limestone brought home by Sir John Richardson in his early travels with Franklin, and which have been mislaid, are also Permian; and in this case, a zone of that age may be said to extend at intervals from Kansas and the Rocky Mountains of Mexico even into the Arctic regions watered by the great Mackenzie River.

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The following Table is thus explained by Professor Ramsay, who attended the meeting of the American Association for the Advancement of Science, held at Montreal in 1857, as the representative of the Geological Society of London:—"In Canada I had the advantage of the able guidance of Sir William Logan, whose maps, reports, and museum reflect so much credit on the Colonial Government; and in a great part of the State of New York I was conducted by Professor James Hall, of Albany, over the most typical sections. With him I also examined his unequalled collection of Silurian and Devonian fossils; and subsequently those in the Geological Museum at Montreal. Chiefly from Mr. Hall, and partly from Mr. Billings, Palæontologist of the Canadian Survey, lists of characteristic genera and species were obtained for all the rocks excepting the Medina sandstone and Oneida conglomerate; the lists for these were mostly derived from Mr. Billings' catalogue of the fossils lately discovered in the Island of Anticosti by Mr. Richardson.

"In North America the Huronian rocks lie unconformably on the Laurentian gneiss, like the Cambrian conglomerate on the more ancient gneiss of the N.W. of Scotland (see p. 199). In ascending order, the Potsdam sandstone occupies the same position with the Lingula flags, and lithologically strongly resembles the gritty beds of the Stiper Stones and those in the Lingula beds of Caernarvon. The calciferous sand-rock and Chazy limestone may also be paralleled with the strata containing Maclurea, Ophileta, &c., in Sutherland, pp. 181, 217.

"The Bird's-eye, Black River, and Trenton limestones occupy the general position of our Llandeilo flags; and, though the trilobites show a mixed character, several of them (Asaphus, Illænus, &c.) are characteristic of our Llandeilo. In the large assemblage of Brachiopoda, these deposits, however, more nearly resemble the British Caradoc than the Llandeilo type. So many fossils, indeed, are common to the Trenton and Hudson River rocks, that lithological distinctions chiefly divide them.

"The Utica slate is often inseparable from the Hudson River beds. Both of them bear the strongest lithological resemblance to the Bala rocks that lie above the igneous rocks of the Arenigs and Arans. In both, black graptolite shale lies at the base, with arenaceous, slaty, fossiliferous beds above them.

"The Oneida and Medina rocks may well be compared with the Lower Llandovery (Pentamerus) rocks; whilst the Clinton group and Niagara shale and limestone present striking resemblances, both in fossils and structure, to the British series between the base of the Upper Llandovery (Pentamerus oblongus) and the top of the Wenlock.

"The Onondaga salt group is singularly destitute of fossils; but, with the exception of its gypsum, is not unlike the muddy, partially calcareous Lower Ludlow rocks. The Lower Helderberg series is, however, much more calcareous than the greater part of the British Ludlow rocks. It is united by fossils with the Niagara series below. It seems possible that the precise equivalents of the uppermost British Ludlow rocks are absent in this part of America. The sudden increase in Spirifers of a peculiar type clearly points out the Oriskany sandstone as the beginning of the American Devonian series, as first shown by M. de Verneuil. A considerable number, however, of Lower Helderberg species pass upwards into the Oriskany sandstone. The red sandstones of the Catskill Mountains belong to that debateable zone which unites the Devonian with the base of the Carboniferous strata."

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TABLE OF THE ORDER OF SUPERPOSITION OF THE LAURENTIAN, HURONIAN, SILURIAN, AND DEVONIAN STRATA OF CANADA AND THE STATE OF NEW YORK, ETC., COMPARED WITH THEIR BRITISH EQUIVALENTS: WITH LISTS OF SOME CHARACTERISTIC FOSSILS. By A. C. RAMSAY, F.R.S., Local Director of the Geological Survey of Great Britain.

British general equivalents.					
DEVONIAN.	Upper.	Old Red Sandstone of Catskill Mountains			Euomphalus depressus, Holoptychius Nobilissimus, and a few plants.
		Chemung group			Sigillaria, Ferns, Lepidodendron, Orthis, Atrypa, Strophomena, Leptæna, Productus, and numerous Spirifers, &c., Avicula pectiniformis, and several others like Aviculopectens.
		Portage group			Fossils few. Orthis, Spirifer, Bellerophon, Goniatites, Orthoceras, Cyathocrinus.
	Middle.	Upper Helderberg group.	Hamilton group.	Genesee slate, Moscow shale, Marcellus shale.	Chonetes, Orthis, Producti numerous; Spirifer, about 17 species; Cyrtia, 20 species; Atrypa reticularis, &c., Rhynchonellæ, *Upper limit of Pentamerus.* Many Lamellibranchiata, Orthonota, Grammysia, Avicula or Aviculopecten, Mytilus Chemungensis, &c. Euomphalus, Pleurotomaria, Bellerophon (like B. expansus). Many species of Goniatites, the largest a foot across. Many Orthoceratites, Encrinites, Palæaster. Trilobites of the genera Phacops, Proetus, Dalmanites, and Homalonotus.
				Corniferous limestone	Encrinal stems, the largest 1⅜ inch in diameter. Atrypa reticularis, &c.; Pentamerus arcuatus, characteristic. Strophomenæ numerous; Merista, Chonetes; Spirifer, 15 species, chiefly short-hinged; Meganteris, Aviculopecten, and other Aviculoid shells, &c.; various Gasteropoda; Cephalopoda, viz. Lituites, Trochoceras, Phragmoceras, Cyrtoceras; Orthoceras, some with annular projecting lamellæ; Goniatites. Calymene Blumenbachii, var. major?; Phacops, Proetus, Dalmanites; Old Red Fishes. Resembles the Hamilton group.
	Lower.	.....		Schoharie grit	Fishes as above. Pentamerus arcuatus, Atrypa impressa (like A. reticularis).
				Cauda-galli grit	Sea-weeds.
				Oriskany sandstone	Orthis unguiformis, &c., Strophodonta, Strophomena depressa?; many large Spirifers; Rhynchonellæ, large; Meganteris, 2 species; many Gasteropoda, Acroculiæ, &c. Assemblage peculiarly characteristic of this division.
UPPER SILURIAN (Murchison).	Upper Silurian.	Lower Helderberg group.	Ludlow beds.	Upper Pentamerus limestone.	Pentamerus pseudo-galeatus. Eleven species of Orthis, some identical with or representative of Niagara species; Lingula, 3 species; Strophomena depressa and S. euglypha, or punctulifera of Hall; Spirifer perlamellosus in immense quantity, S. cyclopterus, S. concinnus, and others; Meganteris elongatus; Merista, numerous; Rhynchonella Wilsoni, varieties; Atrypa reticularis; Avicula, numerous, like Aviculopecten. At this period the paleozoic Gasteropoda of America assumed their greatest development. *Trilobites*—Phacops, Dalmanites, Lichas, Proetus, Acidaspis, Homalonotus, &c.
				Encrinal limestone	
				Delthyris shaly limestone	Pentamerus Verneuilii, &c.
				Lower Pentamerus limestone.	
				Stromatopora limestone	Pentamerus galeatus, &c.
				Tentaculite limestone	Tentaculites ornatus, &c.
		Onondaga Salt-group			Atrypa, Delthyris; Pentamerus occidentalis, like P. Knightii, but smaller; Megalomus Canadensis, Merista, Murchisonia, Pleurotomaria, &c. (Eurypterus remipes in the upper beds.)
		Niagara group (Wenlock).		Niagara limestone	Numerous Corals, chiefly in the limestone, and Bryozoa in the shale. Lowest zone, Cystideans. Many of the fossils, viz. Orthis, Spirifer, Leptæna, Atrypa, are the same species, and others representative of those in England.
				Niagara shale	
	of America.	(Upper Llandovery) Clinton group			Graptolites, G. Clintonensis, G. (Retiolites) venosus, Tentaculites and Cornulites; *Pentamerus ovalis* in upper part, and *P. oblongus* in lower beds; Lingula oblonga, Chonetes cornuta, Leptæna depressa, L. sericea, L. transversalis, and others not European; Spirifer radiatus and Orthis biforata; Tellinomya machæriformis, Posidonia alata, Modiolopsis subulata, Orthonota cincta, Avicula rhomboidea; Gasteropoda; Orthoceras, Ormoceras, &c. Calymene Blumenbachii, Bumastus Barriensis, &c. Anticosti (Billings).

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LOWER SILURIAN (Murchison):

Middle Silurian	(Lower Llandovery.)	Medina sandstone	In New York, Lingula cuneata, common; Atrypa plicata and A. oblata, Modiolopsis primigenia and M. orthonota; Pleurotomaria pervetusta, Fucoids, Cruziana?, &c. In Anticosti (Billings), Stromatopora concentrica, Leptæna alternata, L. subplana, Atrypa congesta, A. reticularis, *Pentamerus Barrandi*, Calymene Blumenbachii.
		Oneida conglomerate	Corals: Chætetes lycoperdon, Catenipora escharoides, &c., Leptæna sericea, L. subplana, and L. transversalis, Strophomena alternata and S. depressa, Orthis lynx and O. testudinaria, Atrypa naviformis, *Pentamerus reversus, &c.*, Bellerophon bilobatus and Calymene Blumenbachii.
Lower Silurian.	Hudson River group (Caradoc or Bala beds).	Hudson River beds	Fossils in great part the same as in Trenton limestone, viz. Tentaculites, Orthis testudinaria, O. subjugata, O. sinuata, O. plicatella, &c., Strophomena alternata, S. planumbona, Leptæna sericea; Orbicula crassa; Rhynchonella increbrescens, Hall; Bellerophon bilobatus; Ambonychia radiata, very characteristic, as in Britain; Modiolopsis modiolaris, common; Avicula demissa, Orthonota parallela. Encrinites: Glyptocrinus basalis, &c.; Asterias (Palæaster), Calymene senaria, Triarthrus Beckii, Trinucleus concentricus, Isotelus megistos, I. gigas. (Clearly equivalent to the Caradoc or Bala beds.)
		Utica slate	Black bituminous graptolitic shale. The Graptolites in this and the Hudson River beds, as given by Hall, are G. pristis, G. mucronatus, G. ramosus, G. sagittarius, G. tenuis, G. sextans, and several other species. Lingula, Orbicula, Orthis testudinaria, Leptæna sericea; Trilobites, chiefly the same as in the division above, Asaphus latimarginatus.
	General grouping like that of the Caradoc, but with some trilobites like those of the Llandeilo flags.	Trenton limestone	Very fossiliferous. Especially rich in Crinoids. Cystideans, Starfish, Asterias (Palæaster) matutina; Chætetes Petropolitanus, C. Lycoperdon, C. columnare; Retepora, Streptelasma; Lingula quadrata, Leptæna sericea, Strophomena tenuistriata, L. alternata, abundant; many species of Rhynchonella (Atrypa), A. increbrescens, &c.; many Acephala, Avicula Trentonensis, Tellinomya, &c.; species of Pleurotomaria, Holopea, and Murchisonia; Bellerophon bilobatus, Asaphus Barrandi, Isotelus gigas, Ceraurus pleurexanthemus and C. vigilans; many Cephalopoda, of the genera Oncoceras, Lituites, Orthoceras, Cyrtoceras, Trocholites, Endoceras; Illænus crassicauda, Phacops callicephalus, Triarthrus Beckii, Calymene senaria, 3 sp. of Acidaspis, Trinucleus concentricus, Olenus, &c.
		Black River limestone	Fossils, as a whole, much the same as those of the Trenton limestone. Ormoceras tenuifilum and Gonioceras unknown in England.
		Bird's-eye limestone	Several species of Murchisonia, M. angustata, &c., and of Pleurotomaria; Orthoceratites. The marks designated "Bird's-eyes" are the ends of Phytopsis tubulosa.
	Maclurea beds of N.W. of Scotland.	Chazy limestone	Bryozoa and Corals of the genera Retepora, Ptilodictya (Stictopora), Petraia (Streptelasma), and Chætetes; with Encrinites; Leptæna, Orthis, Atrypa; Maclurea magna, Scalites, Raphistoma, Murchisonia, &c.; Illænus. Asaphus?; Isotelus gigas?, I. canalis. Ophileta compacta, O.? (Maclurea) sordida, Maclurea matutina, Turbo, and Pleurotomaria?; Orthoceras, 2 sp.; and Sea-weeds.
		Calciferous sand-rock	
	Potsdam sandstone (Lingula flags)		Lingula prima and L. antiqua; Scolithus linearis; Cruziana.
Huronian of America.	[Cambrian of Britain.]		No fossils have as yet been found in this zone.
Laurentian of America.	[Oldest Gneiss of Scotland.]		

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CHAPTER XIX.

ON THE ORIGINAL FORMATION OF GOLD, AND ITS SUBSEQUENT DISTRIBUTION IN DEBRIS OVER VARIOUS PARTS OF THE EARTH'S SURFACE.

CONSIDERING the great quantity of gold which has recently been found in California and Australia, it may be expected that an author who has for many years borne a part in the discussions relative to this phenomenon* should devote a few pages to so engrossing a topic; the more so as my chief article of belief has now proved to be true, viz. that the rocks which are the most auriferous are of Silurian age. The views now put forth will chiefly relate to the geological and mineralogical conditions under which gold has occurred. As a clear understanding of this point may tend, in some measure, to allay the fears of those who think that the metal may be discovered over regions vastly more enormous than the tracts to which it is restricted, certain geological and statistical data and arguments that I have advanced in greater detail in other works are here brought together.

Let us first reflect upon the general fact, that, whilst all the stratified formations are composed either of crystalline and paleozoic rocks, or of secondary and tertiary deposits, gold has never been found in any appreciable quantity in either of the two last-mentioned classes of strata. The vast areas, therefore, which are covered by all such younger formations are excluded from the application of our reasoning; and every one who lives in tracts the

* See Russia in Europe and the Ural Mountains, pp. 437 *et seq.* Trans. R. Geogr. Soc., President's Discourses, vol. xiv. 1844, 1845, in the first of which the Australian rocks were compared with those of the Ural. Trans. Royal Geological Society, Cornwall, 1846, p. 324 *et seq.*, in which Cornish tin miners were incited to emigrate and work for gold in Australia. Report of the British Association for the Advancement of Science, 1849 (Trans. of Sections, p. 60). Proceedings of the Royal Institution, March 1850. Quarterly Review, 1850, vol. lxxxvii., Article 'Siberia and California,' p. 39. Quart. Journ. Geol. Soc. Lond. vol. viii. p. 134. And, lastly, 'Further Papers on the Recent Discovery of Gold in Australia,' presented to Parliament Aug. 16, 1853, p. 43; including my correspondence, in 1848, with Her Majesty's Secretary for the Colonies, on the then known existence of gold in Australia, and tendering my advice as to the manner of opening out useful gold works in the colony.

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subsoil of which consists of such rocks, may at once be assured, that he can never profitably extract gold from them.

Having laid down this generalization, which affirms that by far the largest portion of land on the face of the globe never contains gold, we proceed to consider the nature and limits of the gold-bearing rocks, and then indicate how the chief wealth is derived from superficial auriferous drifted materials or gravel.

Appealing to the structure of the different countries which at former periods have afforded or still afford any notable amount of gold, we find in all a general agreement. Whether, referring to ancient history, we cast our eyes to the countries watered by the Pactolus of Ovid, to the Phrygia and Thrace of the Greeks, to the Alps* and golden Tagus of the Romans, to the Bohemia of the Middle Ages, to tracts in Britain which were worked in old times, and have either been long abandoned or are now scarcely at all productive, or to those chains in America and Australia which, previously unsearched, have, in our times, proved so rich,—we invariably find the same constants in nature. In all these lands, gold has been imparted abundantly to one class only of those ancient rocks whose order and succession we have traced, or to the associated eruptive rocks. The most usual, original position of the metal is in quartzose veinstones that traverse altered Silurian slates (chiefly Lower Silurian), frequently near their junction with eruptive rocks. Sometimes, however, it is partially diffused through the body of rocks of igneous origin. The stratified rocks of the highest antiquity, such as the oldest gneiss (like that, for example, of Scandinavia and the north-west coast of Scotland, pp. 180, 199), have never, as far as I know, borne gold; but there is no reason, *à priori*, why the

* In truth, as above expressed, every old country of Europe, where the rocks were once auriferous, has long ceased to yield any valuable amount of gold. In reference to the Alps, I am indebted to my learned friend Mr. J. W. Cowell for pointing out to me the following passage in Strabo (Book iv. ch. 6. sect. 12), by which it appears that even Imperial Rome was at one time inundated with a glut of gold from her northern mountains:—"Polybius says that in his time the gold mines were so rich about [north of?] Aquileia, but especially in the country of the *Taurisci Norici*, that if you dug but two feet below the surface you found gold, and that the diggings (generally) were not deeper than 15 feet; that in some instances the gold was found pure, in lumps of the size of a bean or a lupin, and which lost only one-eighth in smelting; in others it required more smelting, but was very profitable. Italians aiding the barbarians in the working for two months, gold became forthwith one-third cheaper over the whole of Italy; and the Taurisci discovering this, drove the associate Italians away and monopolized it themselves. At present all gold mines belong to the Romans."

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metamorphosed Silurians of the North Highlands, when in the state of mica slate, chlorite slate, or quartz rock (pp. 179 and 200), should not prove auriferous. Nor has the noble metal been as yet detected in those ancient formations of North America, both older than the Silurian, as described in the last chapter, the Laurentian and Huronian, the latter being the representative of the Cambrian or Longmynd rocks of Britain. The paleozoic accumulations which followed (particularly the Lower Silurian), have, in short, been the deposits which, in the tracts where they have undergone a metamorphosis or change of structure by igneous agency, or have been penetrated by quartz veins, are the *chief* sources whence gold has been or is derived.

Seeing, on the one hand, that the oldest rocks, and, on the other, the medial and youngest deposits never contain gold, and that yet (as will be shown) the metal is of recent accumulation *en masse*, it might seem to follow that there existed in those original deposits which have since become largely auriferous, the elements out of which gold was subsequently brought together in rich veinstones. It is indeed a fact, as will hereafter be shown, that there are fine-grained old schistose sediments in which gold is so impalpably disseminated, that it is difficult to imagine how this diffusion could have occurred if the original menstruum had not contained the elements of the ore. In that diffused state the gold may have remained long after the consolidation of the sediment, until, in ages long posterior, it was run together into metallic veinstones by metamorphic action, or segregated into the lumps and filaments in which it now occurs. But, however we may account for them, the facts are those which I have for many years exposed—viz. that a certain geological zone only in the crust of the globe has been rendered richly auriferous*.

* When preparing this work for press, I received a letter from Mr. Lieber, the State geologist of South Carolina, which, being explained by a second letter from that gentleman, in reply to one which I addressed to him, contains a little table which clearly expresses his views as derived from his experience in South Carolina and the Brazils. Tracing out the peculiar features of the 'itacolumite' and its associated rocks of 'itaberite' and 'specular iron schist,' and a compound of talc and magnetic iron, which he terms 'catawberite,' Mr. Lieber affirms, that these rocks, together with clay and talcose slates, are chiefly auriferous, and that none of the rocks above them ever bear gold, whilst the mica slates beneath are much less productive of the ore. He consequently classifies the whole in ascending order, as Sub-auriferous, Auriferous, and Post-auriferous,—a mineral classification which is in accordance with the data I have long endeavoured to establish by geological and paleontological proofs.

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Gold in Britain.—The British auriferous examples, comparatively small in produce as they have been, will be first briefly alluded to; because the reader can at once refer, in the coloured map of this work, to two districts of Wales wherein gold has been found, and in one of which it is now in the course of very partial extraction. (See the golden spotted patches in N. and S. Wales.)

In the Lower Silurian rocks, about ten miles west of Llandovery, at a spot called Gogofau, near Llan-Pümp-saint, large white quartzose veinstones, traversing slaty masses, were cut into by the Romans, who excavated lofty galleries, which are still open. That enterprising people evidently derived gold from portions of these veinstones. Many gold ornaments have in fact been found at the adjacent Roman station of Cynfil-Cayo, with traces of aqueducts, which were built probably to convey water to wash the gold. Even the grindstones* and troughs used in abrading the hard matrix are yet visible.

In North Wales, where similar but older strata have been more crystallized, and infinitely more penetrated by igneous rocks, gold was not only obtained in ancient times, but is still found to a small extent. In Merionethshire some of the older slaty rocks were ten years ago announced to be auriferous by Mr. A. Dean†. The district then referred to, which lies to the north of Dolgelly, and to the north and west of the small river Mowddach, has since been resurveyed by Professor Ramsay, who has described the precise geological relations and mineral character of several metalliferous lodes, which, poor in lead and copper, are slightly charged with gold‡. The lodes are subordinate to the Lingula flags or Lowest Silurian rocks, and these being traversed by trap dykes (including magnetic greenstone), as well as bounded by a large mass of eruptive rock, are much altered, often into a talcose and chloritic schist, and are traversed by quartz veins containing much iron pyrites. The principal localities where the gold has been observed are Cwm-eisen-isaf and Dol-y-frwynog. One of the veinstones at the latter place consists of white saccharoid quartz, in some of which small flakes of gold are distinctly visible to the naked eye.

Professor Ansted, who has examined the same gold veins *in situ*, reported to me, that at Dol-y-frwynog, the gold is disseminated both in grains and in laminæ enclosed in irregular bands or veins, parallel to the Lower Silurian schists, and contiguous to a poor lode of copper ore; the whole lying near a greenstone with the slaty rocks. The auriferous bands, he says, are made up of numerous threads of quartz and sulphate of barytes, which, besides the grains and flakes of gold, contain crystals of galena and copper pyrites§.

* See Silurian System, p. 368. At the time of the publication of that work (1839) I had not visited the Ural Mountains, and was little acquainted with the nature of gold-bearing rocks and the methods employed for the extraction of the metal, or I should at once have recognized as certain, what I only ventured to suggest, that the rock might formerly have been quarried for the gold it contained. Suspecting that some traces of gold might be detected in the pyritous refuse of the quartz rock, I submitted a little of it to the late eminent chemist, Dr. Turner; but he could not detect a trace of the precious metal. Recently, however, Mr. Warington Smyth and Dr. Percy have detected a small quantity of gold diffused in these quartz veinstones. See Memoirs of the Geological Survey, vol. i. p. 480; also an exposition of the relations of gold, in the 'Lectures on Gold' by E. Forbes, Jukes, Playfair, Percy, Warington Smyth, and Hunt.

† Report Brit. Assoc. Adv. of Science, 1844, Proc. of Sect. p. 56.

‡ Quart. Journ. Geol. Soc. Lond. vol. x. p. 242.

§ Gold often occurs in small strings or threads, which, though rich at the surface, are soon lost in the body of the rock, and this seems to be the case in Merionethshire.

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At a few places in Cornwall* and Devonshire, gold has been long known to exist in small quantities, both in the matrix of mineral lodes and occasionally in accumulations of rolled materials. The Poltimore mine, near North Molton, Devon (where certain schists of Upper Devonian? age are mineralized, and were formerly worked for copper), was said in 1853 to promise a rich auriferous result. But, since the issue of the first edition of this work, the speculation has been abandoned; it having been proved (as I suggested to the noble proprietor would be the case) that no sufficient body of gold-bearing matrix would be found to repay the cost of the works. The coarse, ancient alluvia or gravel of Cornwall, whence the tin ore has been extracted, as well as some other portions of drift in that county, have indeed long afforded small quantities of gold; but, although the largest fragments have occasionally been of the size of a pigeon's egg, none of these superficial accumulations have been considered worthy of continuous exploration.

In Scotland, whilst slender traces† only of gold have been detected in the older crystalline rocks of the Northern Highlands, albeit many of them are now known to be of Lower Silurian age, the metal was formerly found in the slates of the South of Scotland (Lead Hills), which, like those alluded to in North and South Wales, are also of that age. These South Scottish gold mines, after affording a small sum, in the reign of James the Fifth, were, however, abandoned as soon as the cost of production exceeded the value of the ore extracted‡. They occurred in a region where the strata have been much penetrated by porphyries and other igneous rocks.

In Ireland we read the same lesson. It is from the altered Lower Silurian schists of Wicklow, which clasp around the eruptive granite of Croghan-Kinshela, and are traversed by hornblendic greenstones, that gold was derived, and fragments of which, detached from the sides of that mountain and washed down by the rivulets, continue to be still picked up by the natives§.

Now, if any portion of these old slaty British rocks, or their associated eruptive masses, had been largely penetrated by gold, then most assuredly much

* Mr. S. R. Pattison read before the Geological Society (February 1st, 1854) a notice on auriferous quartz rock near Davidstow, North Cornwall, the chief gold-bearing mass of which is the *gossan* of a dyke in a metamorphosed rock of Upper Devonian age, which, mantling round the granite of Roughtor, is also associated with dykes of trap.

† Near Loch Erne Head, a metalliferous veinstone on the property of the Marquis of Breadalbane has recently been found to be slightly impregnated with gold. The gold occurs in a gossan, contiguous to the junction of trap with crystalline limestone and schist (probably of Lower Silurian age), and is associated with arsenical pyrites and lead ore.

‡ See Harkness on the 'Lower Silurian Rocks of Scotland,' Quart. Journ. Geol. Soc. vol. viii. p. 396.

§ The Earl of Wicklow, whose property is in the vicinity of the mountain of Croghan-Kinshela, has collected several "pepitas" of this Irish gold, the largest being about two inches long. They are free from quartz or other rocky matrix, and have been picked out of the debris or coarse gravel on that slope of the hill where a rivulet descends through the property of the Earl of Carysfort. No veinstone *in situ* has ever been detected (Mills and Weaver, Trans. Dublin Society, and Weaver, Trans. Geol. Soc. Lond. 2 ser. vol. i.); and although poor persons have stealthily procured specimens during this century, the quantity has never been sufficient to lead to the belief that really productive diggings could be opened at the Royal Gold Mine of Croghan. Tinstone is said to have been found with the gold here, as in Cornwall and other places. (See Fitton, Trans. Geol. Soc. Lond., 1st series, vol. i. p. 270. The phenomena are well developed by Prof. Warington Smyth, Records of the School of Mines, &c., vol. i. p. 3, with a map.)

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more auriferous debris would have been recognized in the local adjacent gravel; —just as it occurs in all really gold-bearing lands. But, as no rich auriferous sand or gravel is known in any part of the British Isles, we may rest satisfied that in our own country, as in many others, the quantity of gold originally imparted to the Silurian or other rocks was very small, and has, for all profitable objects, been exhausted *.

Even in Bohemia, which produced so much gold in the Middle Ages, and where the Silurian strata are, as we have seen (chap. 15), penetrated by many igneous rocks (and in parts much metamorphosed), there are now no gold works, though other ores (copper, &c.) are profitably extracted; and, just as in the rocky and mountainous tracts of Britain, very few places only can be cited which have been auriferous. The Thüringerwald, and some chains of Central Germany, also anciently afforded a little gold in rare and widely-separated localities †; but these regions, as well as the Peninsula and its "golden Tagus," so auriferous in the classical era, have, I repeat, long since ceased to offer any notable quantity of the precious metal.

The Ural Mountains.—No country furnishes a clearer example than Russia of the dependence of gold on certain geological and mineral relations. Her European territories are, as has been stated, chiefly occupied by slightly solidified, primeval deposits. Under those conditions, and with a total absence of any crystalline rocks, whether of intrusive or of sedimentary and metamorphic characters, not a particle of gold has been discovered in them, over an area larger than the rest of Europe. But where the same formations have been thrown up into inclined and broken positions in the Ural Chain, and have there been pierced by porphyry, greenstone, syenite, and granite, in association with huge masses of serpentine, the very same deposits, so soft in European Russia, have been hardened, crystallized, veined, and rendered highly metalliferous; some even of the igneous masses being also occasionally auriferous.

As the rocks in this chain, which separates Europe from Asia, are now known to be similar in character to those of numerous other auriferous ridges in Siberia and the Altai Mountains of Asiatic Russia, the present description may serve to explain the composition of those vastly larger eastern tracts. The study of this Uralian Chain enabled me to suggest, in the year 1844, by comparison of the rocks of the two countries, that Australia would also prove to be an auriferous

* The reader, who may have attended to this subject, will observe, that the chief argument I have employed in other writings (see note, p. 474) to satisfy the public mind that auriferous sites in the old countries of Europe would for the most part prove slightly profitable only, was, that all such works had ceased in former times for want of remuneration. Let me, however, say, that, whilst I believe the old gold tracts of Europe have, on the whole, been exhausted of their wealth, there may still be found spots where a little profit is attainable. I would further guard any inferences I have drawn from our previous state of knowledge, by saying, that my opinions were formed irrespective of the new inventions in mechanical science. Crushing machines and the improved application of mercury may, indeed, liberate a notable quantity of ore from a matrix of apparently slight value, and thus set at naught the experience of ages. Not pretending to enter into this mercantile part of the question, I adhere, however, to the belief expressed throughout the text, that gold will mainly be found in the old rocks indicated, and will, on the whole, be worked to great advantage only, as during past ages, in the natural debris of those rocks.

† The sands of the river Rhine (which drains so vast a rocky region) are in one part slightly auriferous, but the cost of extraction of the gold has been too great to repay the speculators.

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region. The survey of the Ural Mountains in 1842 led me further to define, within certain limits, the period when the Silurian rocks were chiefly impregnated with gold, and also to affirm that gold, as a distinct metallic mass, is of younger date, in that region, than the associated ores of copper and iron*.

With a watershed for the most part not exceeding 2000 feet above the sea, their highest peaks rarely rising above 5000 to 6000 feet, the Ural Mountains, throughout a north and south range of 18 degrees of latitude, are composed of rocks more or less crystalline; chiefly metamorphosed representatives of the Silurian and Devonian, and occasionally of the Carboniferous age. The Lower Silurian strata are, indeed, to be recognized in a crystalline state only. They are for the most part talcose schists, quartzites, and limestones; whilst the Upper Silurian, Devonian, and Carboniferous, though often also considerably altered (the limestones being frequently converted into marble occasionally dolomitic), offer here and there traces of their characteristic fossils. The flexures and fractures of the stratified rocks (Devonian and Carboniferous), as they approach the western flank of the altered and metalliferous axis of the chain, have been represented in the view of the gorge of the Tchussovaya, p. 386.

The following rough sketch will convey some idea of the wild, central, and

VIEW FROM THE SUMMIT OF THE KATCHKANAR, N. URAL.
(From Russia in Europe, vol. i. p. 392.)

The snowy mountains seen in the distance to the north, are much the loftier peaks of Konjakofski Kamen, &c.

mineralized masses which, in the Northern Ural, peer out, here and there, from amid forests of the gigantic Pinus Cembra. It was taken by myself from the

* See Russia in Europe and the Ural Mountains, vol. i. p. 472 *et seq.* Also Journal of the Royal Geographical Society, President's Discourses, 1844–5.

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summit of the Katchkanar*, a rugged pile of stratified and jointed augitic greenstone, highly charged with magnetic iron. Platinum, as well as gold, has been washed down from the edges of this mountain and carried into the adjacent gorges on the east; though the sources whence these metals have been drifted into the coarse alluvium have not been detected.

While the traveller who simply crosses the Ural in the partial depression followed by the high road to Ekaterinburg will scarcely be aware that he has passed over any dominant ridge, the geologist who explores the mountains from the south along their line of bearing soon perceives that, to the north, their crest is marked by lofty and usually snowy summits, as in the preceding drawing. To the south, the central mass near Zlata-ust consists of altered sandstone and quartzites, forming sharp peaks, that separate Europe from Asia†.

Few chains offer more contrasting outlines than are seen upon the European and the Asiatic flanks of the Ural. On the former the limestones and other stratified rocks are indeed contorted, fractured, and partially changed, as before represented (p. 386), whilst in the centre, as on the eastern slopes, the masses consist everywhere either of highly altered and crystalline Silurian strata, or of the eruptive rocks which pierce them. There only, and particularly where the schists are traversed by veinstones of quartz, or cut by dykes of igneous rocks, has gold been imparted in any quantity to the slaty, talcose, and chloritic strata. Though some efforts were made by the earlier Russian miners to extract gold from the solid matrix by underground works, such a process was not continued; it having been found infinitely more profitable to extract the ore from the broken accumulations of ancient drift, deposited on the slopes of the hills or lodged in the higher valleys wherein small watercourses meander.

The only work at which subterranean mining in the solid rock is still practised, and at a very small profit, is at Berezovsk near Ekaterinburg. There the shaft traverses a mass of apparently metamorphosed and crystalline matrix, called "beresite," resembling a decomposed granite with veins of quartz, in which some gold is disseminated. The syenite of the Peschanka mines, near Bogoslofsk, is likewise impregnated with particles of gold, and the surface degradation of that rock affords profitable washings. Much farther to the east in Siberia, Colonel Hoffmann long ago indicated a tract, where the schistose stratified rocks are equally permeated by the small diffused particles of the metal, imperceptible to the naked eye.

Considering, however, the practice which has hitherto prevailed, it is from

* The following sketch of the approach to this mountain (visited, I believe, by no other European travellers) through the forests, is given in the work 'Russia and the Ural Mountains,' vol. i. p. 392:—"A large chaotic assemblage of loose angular blocks now lay around us, from amid which rose the magnificent Pinus Cembra, towering above all its associates, the rocks being overgrown with pæonies, roses, and geraniums. Such stony features alone would have led us to suppose that we were at the foot of the object of our exploration, when, in a few minutes, the broken and jagged outline of the Katchkanar burst upon our sight under a fine bright sun and amid the merry song of birds. The dull, wet, and marshy woodlands were now exchanged for sunshine and rocks. . . . . Accustomed as we have been to the wildest features of the Highlands of Scotland and the Alps, we are unacquainted with any scene presenting a finer foreground of abruptly broken rocks, and never certainly had we looked over so grand and trackless a forest as that which lay around us, and from which some straggling distant peaks (those on the north only being still capped with snow) reared their solitary heads."

† See the frontispiece of 'Russia and the Ural Mountains.'

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the broken or drifted materials only that the Uralian gold has been ground out by water-mills and collected for use. This is notably the case on the east flank of the chain*, where the mixed and coarse detritus of all the hard rocks has, at certain spots, proved to be auriferous, and in some cases much more so than others; there being very large tracts indeed where no trace of gold can be detected even in similar detritus.

On the east flank of the South Ural (S. of Miask), where the chain is still auriferous, conical igneous rocks have burst out, as represented in the annexed drawing, and constitute a picturesque scene. The low rich grassy grounds around this Lake of Aushkul, in the country of the Baschkirs, are, to some little

LAKE OF AUSHKUL, S. URAL.

(From a lithograph, 'Russia and the Ural Mountains,' vol. i. p. 359. The Holy Mount of the Tatars is opposite, and the Ural range is seen in the distance.)

extent, auriferous; the gold having been derived by debacles of former periods, which denuded the surfaces of the slaty and quartzose chain (as seen in the distance), or the adjacent conical hills of greenstone, altered schists, porphyries,

* The reader must recollect that the superficies of all the localities of the Ural Mountains in which gold has been found, united, amounts but to a very small part of the whole chain. Incalculably more is the proportion diminished between rocks which from their nature might be, but are not, auriferous, and those of similar structure which really contain gold, when we extend researches into Central and Eastern Siberia. Thus, gold-works are known only at one spot in the western side of the watershed, viz. at Chrestovosdvisgensk. It was there that most of the few small diamonds found in the Ural chain were detected in coarse ancient drift. They were no longer discovered when I visited that place, and traversed the wild, wooded chain by the Katchkanar to Nijny Turinsk. See 'Russia in Europe and the Ural Mountains,' pp. 391–480.

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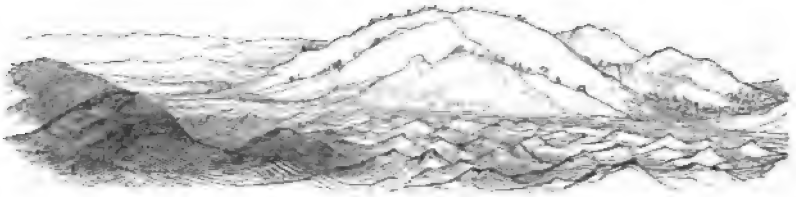
syenite, and serpentine surrounding the lake. The slopes and depressions are partially occupied by the gold-bearing debris †.

The extent to which limestones of the Carboniferous age have been altered on the eastern flank of the South Ural is instructively seen at Cossatchi-Datchi, a remote spot visited by my companions and myself, and where also a little gold has been found.

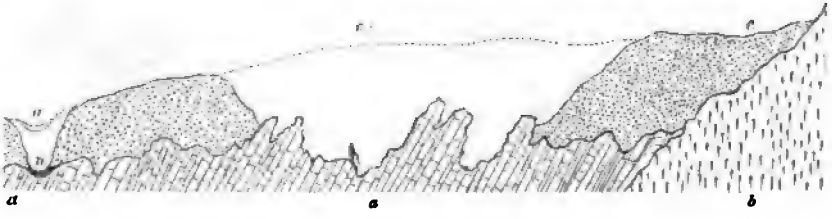


HILLS OF COSSATCHI-DATCHI.
(From 'Russia and the Ural Mountains,' vol. i. p. 439.)

The hills forming the background of this sketch are composed of eruptive rocks and some old schistose strata, whilst in the foreground a little basin is occupied by a number of small conical hillocks of limestone. Their form and mineralized condition are probably due to the action of gaseous vapours and change of the original substance; since not only the traces of bedding are obliterated, but the rock has been rendered fetid and saccharoid, breaking upon a slight blow of the hammer. In this case the metamorphic action, however it may have been produced, has just been sufficiently intense to render the limestone as pulverulent as sugar; but it has left numerous organic remains so uninjured, that they are easily removed from the matrix ‡.

At the Soimanofsk mines, south of Miask, great piles of ancient drift or gravel

DIGGINGS AT THE SOIMANOFSK MINES.
(From 'Russia and the Ural Mountains,' vol. i. p. 487.)



† The rock in the foreground on which we stood is a compound of diallage and serpentine, and is to some extent magnetic. The most striking of the conical mounts is the Holy Hill of the Baschkirs. ('Russia and the Ural Mountains,' p. 437.)

‡ After enumerating upwards of thirty species of these fossil shells, my companions and myself thus spoke of them:—"Those alone who have the same respect for a true characteristic fossil as ourselves, can imagine the feelings of delight with which we here found congregated in one natural Siberian storehouse so great a number of shells, some of which we could not distinguish from well-known forms of the mountain limestones of Yorkshire, Westmoreland, and Derbyshire, nor others from species which are abundant in the same formations in Belgium and France! .... Without this discovery we could not have ventured to affirm, that many other adjacent masses of crystalline limestone immersed among the granites and trappean rocks of these mountains belonged to similar or associated deposits." ('Russia and the Ural Mountains,' vol. i. p. 44.)

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having been removed for the extraction of gold, the eroded edges of highly inclined crystalline limestones have been exposed, which, from being much nearer the centre of the chain than the above, are, I believe, of Silurian age. It is from the adjacent eruptive serpentinous masses and slaty rocks, *b*, that the gold shingle, *c* (usually most auriferous near the surface of the abraded rock, *a*), has been derived.

The tops of the highly-inclined beds, *a*, are, in fact, rounded off, and the interstices between them worn into holes and cavities, manifestly by very powerful aqueous action. Now here, as at Berezovsk (of which hereafter), mammoth remains have been found. They were lodged in the lowest part of the excavation, at the spot to which the small figure of a man is pointing, and at about fifty feet beneath the original surface of overlying coarse gravel, *c**, before it was removed by the workmen from the vacant space under the dotted line. The feeble influence of the existing stream, *n*, in excavating even the loose shingle, is seen at the spot marked *o*, the bed of the rivulet having been lowered by manual labour from its natural level, *o*, to that marked *n*, for the convenience of the diggers.

In some spots the gold-bearing alluvium is a heavy clay; in others it is made up of fragments of quartz veins, chloritic and talcose schists, and greenstone, which lie upon the sides of the hillocks of eruptive rocks †. It was from the infillings of one of the gravelly depressions which I visited, between these elevations south of Miask, that the largest lump of solid gold was found, of which at that time (1824) there was any record ‡. The diggings by which the gravel or local drift was cleared away from around the vertical masses of rock, the surfaces of which have been so much eroded and channeled out, are expressed in the following diagram.

No watercourse sufficiently powerful to transport a single block, much less to spread out broad accumulations of such coarse materials, now flows into this upland depression. Nor could the action, during millions of years, of such an agency as that of the puny rivulets which now meander in parts of the gravelly low ground, account for the eroded and highly-worn surfaces of the rocks, whether crystalline limestones, quartzites, greenstone, porphyry, or serpentine. We are thus necessarily compelled, by all the evidences, to adopt the belief, that on the Asiatic side of the Ural, as in many parts of Europe, the transport of vast masses of drift was accompanied by powerful and long-continued aqueous abrasion, most probably marine, of the summits and slopes of the adjacent auriferous hills.

Whatever may have been the period when the rock was first rendered auri-

† The auriferous shingle, gravel, or sand of the Ural Mountains is poor in percentage in comparison with what has of late years been discovered in California and Australia. Though very large "pepitas" or nuggets have occasionally been found, much of the auriferous ground considered worth working in Russia, where labour is cheap, and water-power for crushing is everywhere at hand, would, if situated in Australia or California, be little heeded.

‡ This "pepita," weighing ninety-six pounds Troy, is still exhibited in the museum of the Imperial School of Mines at St. Petersburg. Since the first edition of this book was published, a very much larger nugget was discovered in the Mines of Victoria, 120 miles N. of Melbourne. This specimen, called the Blanch Barkly nugget, which was exhibited in London, weighs 1743 ozs. 3 dwts., or 146 lbs. 3 dwts. Troy, of which 6 ozs. only are estimated as matrix. As the Bank of England must be the purchaser, let us hope that it may be preserved as the property of that corporation in the British Museum, and be there viewed as a national treasure.

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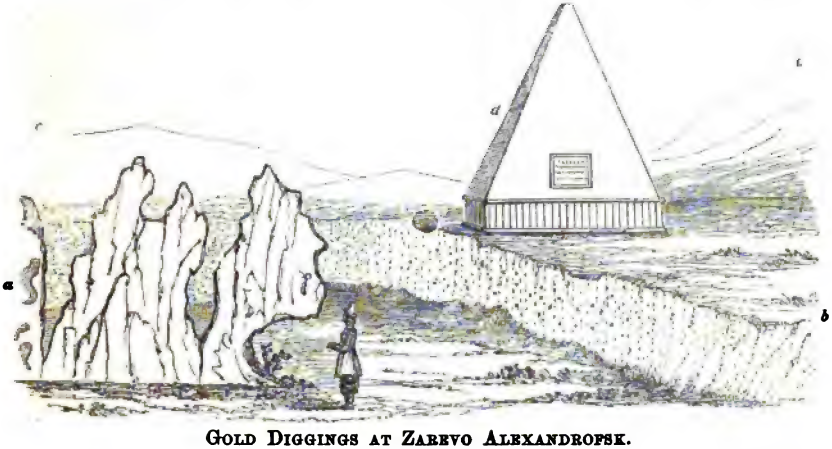
ferous, the relative date when the Uralian gold was superficially distributed is clearly indicated; for the detritus contains in many places remains of the same extinct fossil quadrupeds as are found in the coarse drift-gravel of Western Europe.

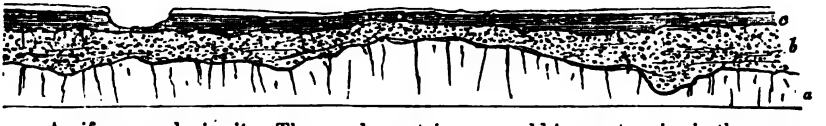


GOLD DIGGINGS AT ZAREVO ALEXANDROFSK.

a. Ancient rocks consisting of talc schist, with veins of quartz (original matrices of gold), penetrated by concretionary felspar rocks, greenstone, &c. *b*. Coarse shingle and gravel about twelve feet thick, in which the great "pepita" was found. *c*. Hills from which the chief debris, *b*, was derived. *d*. Pyramid erected to commemorate the visit of the Emperor Alexander the First.

The Elephas primigenius or Mammoth, Bos aurochs, Rhinoceros tichorhinus, with gigantic Stags, and many other mammalia, were unquestionably contemporaneous denizens of Europe and of Asia, as respects Siberia. They appear to have been exterminated, if not simultaneously, at least previously to the existing conditions of the earth's surface in the northern hemisphere; the Bos aurochs being the only one of these huge mammals which, as far as we know, has been preserved to our days*.

GOLD SHINGLE NEAR EKATERINBURG.



a. Auriferous rocks *in situ*. These rocks contain some gold in quartz-veins in the mass of a metalliferous lode of soft granitoid composition, called, as before said, Beresite, by the Russian miners. It is the only mine in this chain, or in Siberia, which is worked underground, and though very shallow, scarcely repays the expenditure. *b*. Debris with gold and Mammoth bones. *c*. Alluvial clay covered by humus and bog earth.

This diagram explains the relations of the coarse gold-bearing drift with Mammoth bones, as seen at the Bérézof mines near Ekaterinburg.

* The Bos aurochs was probably saved by having inhabited an isolated spot in Western Russia near the forest of Biela vieja in Poland, where the herd now lives, and by having been there locally exempted from the causes of that great destruction which befell their associates. This geological view is fully explained by me, accompanied by an excellent account of the Bos aurochs by Professor Owen ('Russia in Europe and the Ural Mountains,' vol. i. p. 503 *et seq.*).

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Before we quit the consideration of the Ural Mountains, the reader may be reminded that, throughout the length of 500 miles, the rocks contain the precious metal at wide intervals, and in limited patches only. Having indicated the geological period of the superficial gold drift, let me also here advert to a suggestion of my own concerning the era at which the rocks were impregnated*. It has been already stated, that no secondary formation contains veinstones charged with any notable quantity of gold, and that when the metal is found *in situ*, it is chiefly in metamorphosed strata of Silurian age, occasionally in Devonian, and rarely Carboniferous, or in the associated eruptive rocks. Now, it would seem that in the Ural Mountains the gold must have been segregated in separate masses in these formations at a comparatively modern geological period. In the first place, the western flank of the Ural chain offers strong evidence that the process had not been effected when the Permian deposits were completed. During that period, vast heaps of pebbles and sand, all derived from a pre-existing Ural chain (the older stratified rocks of which had even then undergone much change), were spread out over the lower country on the west. Together with fragments of all the rocks, sedimentary or igneous, which are known in the chain, specimens of magnetic iron and copper ore, large quantities of which abound in the range, are not uncommon in this Permian deposit, but nowhere does it contain visible traces of gold or platinum. Had those noble metals then existed in the Ural Mountains, in the segregated lumps and strings which now prevail, many remnants of them must have been washed down together with the other rocks and minerals, and being indestructible, must have formed part of the old Permian conglomerates. On the contrary, when the much more modern debacles that destroyed the great animals, and heaped up the piles of gravel just described, proceeded from this chain, then the debris became largely auriferous. It is manifest, therefore, that the rocks were chiefly charged with gold—*i. e.* the chief lumps and strings of it were run together—during the intervening time.

What then was probably the geological period when these rich auriferous accumulations in the Uralian rocks took place? We cannot believe that it occurred shortly after the Permian era, nor even when any of the secondary rocks were forming, since no golden debris is found even in any of the older tertiary grits and sands which occur on the Siberian flank of the chain. If, then, the mammoth drift be the oldest mass of detritus in which the gold of this region occurs abundantly, not only in the Ural, but in other parts of the world, we are led to believe that this noble metal, though for the most part originally deposited in, or diffused through, the mass of the ancient Silurian sedimentary deposits, was only brought together into rich veins and separate lumps and

* See the work on 'Russia and the Ural Mountains,' vol. i. p. 472 *et seq.*

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strings at a comparatively recent period,—*i. e.* a short time (in geological language) before the epoch during which powerful and widely-extended denudations took place, and during which the large extinct mammalia perished*.

That the gold which occurs in quartz veins in the solid slate rocks resulted from an interior agency, in which heat and electricity were combined with water or vapour, might be suggested, if we judged from the appearance which the strings and expansions of the metal indicate as they ramify through the chinks of the hard rock, or from the grains diffused in its mass. We might also suppose that the prevalent matrix of quartz, whether ejected from beneath, or poured in from above, was in a soft and gelatinous state when it filled the cavities, resembling the siliceous "sinter" which now rises in a fluid spout from the Geysers, and, on falling, coagulates into a modern quartz rock around the volcanic orifice.

In viewing the widely-attested fact of the dispersion of auriferous debris derived from the surface of certain rocks during some of their last great denudations, we might be naturally led to favour the suggestion of Humboldt, that the formation of gold had some closer relation to or dependence upon the atmosphere than that of the baser metals, lead, copper, and iron. My eminent metallurgical associate, Dr. Percy, who has detected minute quantities of gold in almost all lead ores, has, however, told me that he is disposed to believe that the precious metal may have been thrown down by deposition from an aqueous medium.

This suggestion is indeed borne out by the fact that Hoffmann discovered, in one district of Siberia, that the clay-slate contained a certain amount of gold disseminated impalpably through the mass of the rock.

But what I contend for is, that however originally so diffused in the

* In many instances gold is, I know, associated in the same veinstone with other ores—such as silver, or argentiferous galena, and with various ores of copper and iron—magnetic iron being, indeed, a very frequent accompaniment; whilst the association with tin-stone has before been alluded to. Such occurrences do not invalidate, but strengthen, the view derived from the phenomena in the Ural Mountains; for, as copper and iron ores are frequently found in old conglomerates or pebble beds of secondary age, and lumps of gold have never been detected in them, I see no means (explain the phenomena as we may) of evading the inference, that no great quantity of gold ore was formed (certainly not in the Ural Mountains) until the comparatively recent epoch indicated in the text. In the work 'Russia and the Ural Mountains,' vol. i. p. 473, the inference is thus stated:—"Whether, therefore, we judge from the total absence of auriferous matter in the ancient (Permian) conglomerates on the west, and in the tertiary grits on the east, or from the absolute materials in the whole series of regenerated deposits, we conclude that the chain became (chiefly) auriferous during the most recent disturbances by which it was affected, and that this took place when its highest peaks were thrown up, when the present watershed was established, and when the syenitic granite and other comparatively recent igneous rocks were erupted along its eastern edges."

The reader who wishes to have fuller information on the subject of Uralian and Siberian gold, must consult Humboldt's 'Asie Centrale;' 'Reise nach dem Ural,' &c., by Humboldt, Rose, and Ehrenberg, with the valuable mineral description of M. Gustaf Rose; various memoirs by Helmersen and Hoffmann in the 'Annuaire des Mines de Russie;' and Adolf Erman (Reise um die Erde), as well as an account of the general diffusion of gold and a valuable gold map of the world by that author.

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matrix, the ore was segregated from the matrix, and formed into veins, geodes, and strings, at a comparatively recent period.

Again, whatever may be the correct hypothesis as to the original mode of accumulation, the fact is undeniable, that, wherever the veinstones in the solid rock have not been ground down by denudation, and remain as testimonials of the original seat of the gold, the portions which have as yet proved to be the richest are those which are at or nearest the surface. Experience too, dearly bought in numberless instances, has taught the miner, throughout long ages, that in his efforts to follow the veinstones downwards, by deep shafts, into the body of the rock, he has either, except in rare instances, found the gold diminish in volume, or so difficult to obtain, that the cost of extraction has been greater than the value of the metal.

The points which have been alluded to, as drawn from personal observation in the Ural Mountains, are found to have a world-wide application in every tract which has been or is still auriferous. Thus, the giant chain of the Andes, which has for ages afforded much gold in its range through Chili, Peru, and Mexico, is essentially of the same composition. The Indians, who lived in tracts adjacent to those slaty mountains, followed the simple process of picking the shining material from the gravel, sand, and shingle derived from the chain; so that when the Spaniards, the best miners of the sixteenth century, first colonized South America, they naturally inferred that, if ignorant natives could thus gather sufficient quantities of gold to roof the palaces of their sovereigns, they, as skilful Europeans, might extract incredible quantities from the bowels of mountains, the mere detritus of surfaces of which had contributed such a vast amount of gold. But, as frequently as deep mines enriched the Spanish speculators who sought for copper and silver, so surely gold mining in the solid rock proved abortive*, owing to the slender *downward* dissemination of gold in a hard and intractable matrix.

As the phenomena described are common to many countries, the accompanying diagram is annexed, to convey, as far as possible at one view, a popular idea of the chief relations under which gold has been distributed over the surface, so as to be profitably collected by mankind.

* It has been too much the habit to underrate the capacity and skill of the old Spanish miners, though it is known from Humboldt, that during the government of the monarchy in South America many of their works were well conducted; the subsequent operations having been paralysed chiefly by the political revolutions which have occurred in those countries. If the former trials of Spaniards to procure gold with profit from deep mines in the solid rock, and which were proverbially failures, do not satisfy living speculators, let me refer them to similar results in our day, and trials by our own countrymen. Among these, I would specially allude to the well-known mine of Guadalupe y Calvo, near Durango in Mexico, worked by British skill and capital, where, according to information I received from one of its ablest directors (my friend the late Col. Colquhoun, R.A.), the works, which afforded a moderate profit near the surface, became less productive as the mine deepened, and finally failed altogether; the gold having thinned out, and its place being entirely taken by argentiferous galena. See Quarterly Review, art. 'Siberia and California,' vol. lxxxvii. p. 410.

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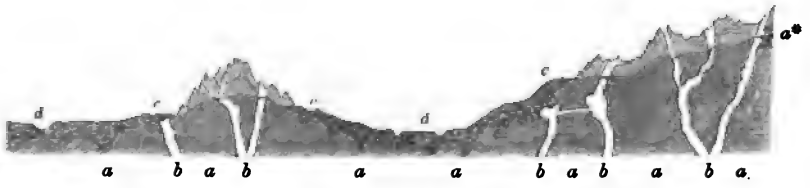
IDEAL REPRESENTATION OF THE ORIGINAL POSITION OF GOLD IN THE OLD SLATY ROCKS, AND ITS SUBSEQUENT TRANSPORT INTO HEAPS OF GRAVEL.

(From a large diagram exhibited in 1850, at the Royal Institution.)



The rocks, *a*, are the ancient metamorphic masses, chiefly of Lower Silurian age, and now often in the condition of talcose, micaceous, chloritic, felspathic, or siliceous slates, which have been traversed by auriferous veinstones, chiefly quartzose, *b*. All along their present dark summits, *a**, is seen a lighter-tinted outline configuration, which represents the condition of the auriferous ridges before their summits were subjected to that destruction and abrasion by which great heaps of drift and gravel were transported from them, so as to form the hillocks, *d*, that cover the adjacent slopes and fill up the gorges and depressions. The first or highest of these drifts, *c*, constitute the "dry diggings" of the miner; the lower heaps, *d*, in which streams meander, being the "wet diggings." As it is impossible to represent in one diagram all the conditions under which gold was originally formed in the rocks, I have merely selected the usual case of veinstones (*b*, *b*), the higher or destroyed surfaces of which were the richest.

Gold of Australia.—The extraordinary quantity of gold which has been poured into Britain from her Australian colonies during the last few years has been chiefly procured, like most of the gold in the other tracts described, from superficial accumulations of shingle, gravel, sand, and clay, derived from the wearing away of adjacent hard rocks, whether of aqueous or of igneous origin.

Having, in the year 1844, recently returned from the auriferous Ural Mountains, I had the advantage of examining the numerous specimens collected by my friend Count Strzelecki, along the eastern chain of Australia. Seeing the great similarity of the rocks of those two distant countries, I had little difficulty in drawing a parallel between them; in doing which I was naturally struck by the circumstance that no gold "had *yet* been found" in the meridional Australian ridge, which I termed in anticipation the "Cordillera†." Impressed with the con-

† The announcement that "no gold had yet been detected," which was printed in my Presidential Discourse, Trans. Roy. Geogr. Soc. 1844, is the clearest proof of my ignorance of a trace of the metal having been discovered by any one. Some time after the practical opening out of the gold mines, however, facts transpired, which were totally unknown to me when I ventured upon my comparison. Thus it appeared that Count Strzelecki himself discovered traces of gold in 1839; but, on relating the fact to some friends and to the Governor of New South Wales, Sir G. Gipps, secresy was enjoined, and the Count never more reverted to the subject—not even in his own work of 1845. It also appears that the Rev. W. C. Clarke wrote to a friend in the colony (1841), mentioning that he had found gold ore; but this circumstance remained as much unknown to myself and all European men of science as the other. My views, whatever they may be worth, were therefore formed quite irrespectively of any such proceedings, as the following extract from a letter of my friend Count Strzelecki to myself, received whilst the first edition was passing through the press, amply testifies:—"Nothing can give me greater pleasure and comfort at any time, than to bear my humble testimony to the inductive powers which you displayed on the occasion of your predictions in regard to the existence of gold in

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viction that gold would, sooner or later, be found in the great British colony, I learnt in 1846 with satisfaction that a specimen of the ore had been discovered. I thereupon encouraged the unemployed miners of Cornwall to emigrate and dig for gold, as they dug for tin in the gravel of their own district. These notices were, as far as I know, the first printed documents relating to Australian gold.

At that time, California, inhabited only by pastoral Indians and a few missionaries and Spanish herdsmen, was, it will be recollected, equally unknown to be auriferous. Its rich alluvial soil had not then been removed from the surface, and the accident at Sutter's Mill, in 1847, had not exposed the gold in the gravel and shingle beneath it. We can still better understand how this should have been the case with regard to vast tracts of Australia, where similar mineral constants exist, but where, instead of a comparatively advanced people, like the Mexicans or Peruvians, a wretched race, incapable of appreciating the uses of the precious metals, had been for ages the sole inhabitants of a vast continent.

Unwilling to offer what must be a very imperfect epitome of the distribution of gold in Australia, I may, however, be permitted to say a few words on a subject to which I called the practical attention of my countrymen for several successive years previous to the discovery of the gold-fields of that vast region.

At or before that period, geological descriptions of various parts of Australia had been published by Mitchell, Strzelecki, Jukes, &c., without any allusion whatever to *gold*. The Rev. W. B. Clarke did, however, rouse the attention of the inhabitants of New South Wales in 1847 to the auriferous character of these rocks, and indicated, as I had previously done, their similarity to the rocks of the Ural Mountains, including the meridional direction of the two chains. This zealous geologist has since explored the largest range of its gold-bearing lands over upwards of six degrees of latitude, or from the Peel River on the north to the Australian Alps of Strzelecki on the south, where the watershed or Cordillera, rising in Mount Kosciusko to 6500 feet above the sea, trends south-eastwards into the province of Victoria. From this author, and from the voluminous details published for the use of the Houses of Parliament*, as afforded by Stutchbury and others, as well as from the

Australia; and consequently I can affirm now, as I did, and do whenever a necessity occurs, that I never mentioned my discovery or supposed discovery of Australian gold to you, prior to your papers on the subject, nor after their publication."

Having disposed of other cases in the first edition, I now simply affirm, that no one, whether in Britain or the colonies, had for several years *printed* anything on the auriferous characters of the Australian rocks except myself, and that my memoirs of 1844, 1845, and 1846 are the earliest publications relating to this subject. See note, first page of this chapter, for reference to all my works on this subject.

* See 'Blue Books' relative to the recent Discovery of Gold in Australia, presented to both Houses of Parliament, 1852–53. For my own connexion *officially* with this subject in 1848, see the Papers on the same subject, presented August 16, 1853, p. 43.

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work of Mr. Hargreaves*, who first proved in 1851 the great value of Australian gold-mining, it was ascertained that the parallel I had drawn in 1844 between the rocks of the chain which I had termed the "Australian Cordillera" and those of the Ural Mountains is well sustained†. Just as in Siberia, the greatest amount of gold is found in heaps of debris, or old alluvia, derived chiefly from veinstones in old slaty rocks, and often adjacent to or associated with eruptive rocks, whether granites, porphyries, or greenstones. I also assumed that the chief auriferous slaty rocks of Eastern Australia are of the same age as the central masses of the Ural, viz. Lower Silurian; because, like them, they are overlaid in parts by strata which contain Pentameri, Trilobites, and Corals, indicative of the Upper Silurian group. Many of these last have been identified by my friend Mr. Lonsdale, who considers some to be Upper Silurian, and others referable to the Carboniferous era. The shells, examined by Mr. Salter, confirm this conclusion; and the carboniferous strata, with European forms of life, appear to be clearly separable from the Devonian. These Lower Paleozoic rocks are followed by Devonian and Lower Carboniferous strata. The overlying coal is distinct from the lower formations.

Whilst the most prolific sources seem to have been the quartzose veinstones which traverse the Lower Silurian slaty rocks, we are further instructed, that in Australia, as in the Ural Mountains, there are tracts wherein gold is diffused in small and often imperceptible particles through the body of certain granitic rocks‡, specially those (according to Mr. Clarke) which are hornblendic or syenitic; the limestones, however, in both countries are partially auriferous only. There is, besides, this striking coincidence between Australia and the Ural, viz. that both chains have a main *meridian* direction; the strike of the old slaty rocks and also of the chief gold veins being from north to south.

In respect to Victoria, which, of all the Australian colonies, has proved to be much the most productive of gold, the age of the slaty rocks con-

* See Hargreaves, 'Australia and its Gold-fields,' 1855.

† Few circumstances have more gratified me than that several of the leading men of New South Wales (including Sir Charles Nicholson and Mr. Donaldson) should, on revisiting England, have spoken out publicly as to the value which attached, in New South Wales, to my early comparison of that region with the Ural Mountains, and of my prediction respecting the auriferous character of Australia. At the first Anniversary Dinner of the Australian colonists from New South Wales, Victoria, South and West Australia, and Tasmania, which took place on the 26th of January last, Sir Charles Nicholson, formerly Speaker of the House of Representatives of Sydney, and now at the head of the University of that metropolis, asserted from the Chair, that his brother-colonists agreed with him in the sentiments he expressed; and this he repeated at a great meeting in the Town Hall of Leeds, on the 29th of September last.

‡ See 'Russia and the Ural Mountains,' vol. i. p. 483, where it is stated, "The fact is, then, that though gold has frequently been, and is for the most part, formed in quartzose and other veins which either have penetrated or been separated from the mass of the slate formation (and of these the Ural affords countless examples), it has also been diffused in some tracts throughout the whole body of the rock, whether of igneous or of aqueous origin."

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taining the auriferous veins has been still more clearly determined. Mr. Alfred Selwyn*, the colonial geologist, cites the occurrence of about sixty species of Lower Silurian fossils, including Trilobites, Graptolites (Didymograpsus, &c.), and Lingulæ, which will be described by Professor F. M'Coy. Mr. Selwyn has further recognized, in Victoria, gold-bearing superficial drifts of three distinct stages, lying above each other; the lowest or oldest of them containing the remains of wood and seed-vessels, differing little from the present vegetation. Even the cones of the Banksia, a tree still prevalent in Australia, have been brought home by Mr. Redaway from one of the bottom drifts, and identified, at my request, as such by the late illustrious botanist, Robert Brown, who first discovered and named the genus. A local distinction in these tertiary gold drifts or detrital beds of Victoria is, that they have been overflowed and even interlaced by basaltic coulées, which evidently proceeded from terrestrial volcanos, inasmuch as the vegetable matter beneath them has been charred and destroyed *in situ* by the eruption. This phenomenon, as first adverted to by Mr. Selwyn and Mr. H. Rosales, exhibits a strong analogy to California†, Mexico, and South America. In all these countries igneous eruptions have burst forth on terrestrial surfaces, at periods posterior to those powerful subaqueous abrasions of the rocks which formed the chief masses of drift‡. Just as in the Ural Mountains (pp. 483, 485), these gold drifts of Victoria, like others described by Mr. Clarke in New South Wales, contain the bones of extinct species of quadrupeds§: in these latter cases, however, the animals are peculiar to the Australian continent.

By consulting the Reports of Mr. Selwyn, it will be found that he refers, as above stated, the auriferous *drifts* to three periods of time, two of which he considers to be of *Tertiary* age, and the most recent of modern date or pure alluvial action. At first sight the reader might

* See a reference to the successful labours of this geologist in North Wales, p. 91.

† Mr. J. S. Wilson, who, after a residence in South Australia, passed three years as a gold miner in the Sierra Nevada of California, communicated a memoir on the auriferous rocks of that region to the Geological Society of London. From his own observation and experience he affirms the fact of the downward impoverishment of gold-bearing quartz veins, and he demonstrates that the richest produce is essentially derived from loose superficial debris. The quicksilver (cinnabar) which is extracted from the coast range of California, occurs in veinstones, in clay-slate (Silurian), as in the Sierra Morena of Spain.

‡ In addition to his determination of the age of the original gold-bearing rocks, and the three derivative sediments into which he divides their detritus in Victoria, Mr. Selwyn thus writes to Prof. Ramsay:—"A somewhat remarkable fact in connection with nearly all the great granitic masses which I have examined is, that, although they invariably alter the slate rocks near their junction and send veins into them, they do not in the slightest degree affect the general strike or dip of those beds, but appear to have themselves partaken of the movements which placed those Silurian strata in their highly inclined and contorted positions, and gave them their very uniform meridional direction." He adds, "There is very little slaty cleavage till we get low down into the Llandeilo beds."

§ See Rev. W. B. Clarke, Quart. Journ. Geol. Soc. 1855, p. 405, where much information is brought together by the author.

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suppose that these data are in opposition to my previous statement, that Secondary and Tertiary rocks have not furnished gold. But such is not the case; for all I assert is, that no veinstones or original segregations of gold worthy of notice have ever been found in such Secondary or Tertiary rocks, but are confined to the paleozoic rocks, and chiefly to the Lower Silurian and their associated igneous masses. The gold *drift* which most prevails, and which in Siberia, as in many other countries, has afforded the most gold, is truly a Tertiary accumulation of Pliocene age, being charged with the remains of extinct mammalia, as reiterated from my former works in this chapter. The data, however, which are here contributed by the researches of Mr. Selwyn are new to geologists, since they appear to indicate that one of the gold drifts of Victoria is of Miocene age. Still it was one of those drifts by the medium of which the gold was abstracted by what I conceive to have been a powerful denudation from the parent rock, just as in the subsequent or Pliocene time. The peculiar features of the successive distribution of the auriferous drifts of Victoria will doubtless be as well explained by Mr. Selwyn*, as I know they will be beautifully illustrated, judging from his coloured diagrams which are now before me.

The observations of Mr. John Phillips, a gentleman who, in the year 1847, called my attention to the existence of traces of gold in South Australia (in accordance with my hypothesis), agree generally with those of Mr. Selwyn respecting the rich detrital accumulations†.

The local character of the gold accumulation of Australia has in the last few years been ascertained by the close examination of the large Peel River tract by my friend M. Odernheimer, who, uniting the practical habits of the miner with an intimate knowledge of mineralogy, has shown how in that fine pastoral region the gold-ore occurs in small quantities only. The thin quartz veins in which the ore occurs lie usually in greenstone or diorite; whilst he holds the theoretical opinion, that there the gold results from the decomposition of auriferous iron-pyrites, diffused also through hornblende-rock, syenite, porphyry, and breccia, as well as greenstone. Chromate of iron, hematite, and magnetic iron, as well as several precious stones, have been recognized in that region‡.

The public of Australia have also been made acquainted with the manner in which the gold occurs in the original quartz veins of the Lower Silurian rocks, whether they be in the proximity of granite or not, or diffused in the gravel derived from such rocks, by the Reports

* See Quart. Journ. Geol. Soc. vol. xiv. p. 533.

† See Rosales on gold drift below basalt, and on two auriferous beds, Quart. Journ. Geol. Soc. 1855, p. 397. See also Abstracts of Proceedings of Geol. Soc. Lond., Session 1857–8, p. 46 *et seq.*, including valuable notes and memoirs by Mr. Selwyn, Mr. Phillips, Mr. Redaway, and Mr. Rosales.

‡ See Quart. Journ. Geol. Soc. vol. xi. p. 399; also a paper on Australian Gems, by Mr. G. M. Stephen, ibid. vol. x. p. 303.

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of the Mining Commissioners of Victoria, Professor M'Coy, Mr. Selwyn, and other gentlemen*.

While these Reports extend very largely the areas over which it is reasonably inferred that the golden detritus will be found to extend, whether in depressions or on the slopes of the old slaty Silurian rocks (an extent which can only be precisely measured off when adequate geographical maps shall have been prepared), the Commissioners point out the reckless and ignorant manner in which many speculators are sinking shafts in proximity to each other in the so-called "quartz reefs," and often missing the vein,—whilst one successful shaft sunk in the right direction, with an adit, would serve the purposes of several proprietors.

They also show, that the evidence given before a select committee of the House of Legislature has been sustained, to the effect, that "auriferous drifts must from their very nature be quickly worked out in any one spot." The Commissioners add, that they have taken great pains to investigate these points on the gold-fields, and the result has been the most complete confirmation of the evidence alluded to. Some of the old alluvial gold-fields, in full prosperity when that evidence was given, are now comparatively deserted, and there can be no longer any difference of opinion respecting that class of drifted gold deposits.

With regard to the evidence touching the yield of gold from deep mining into the "quartz reefs," concerning which there was the greatest scepticism, the same result seemed at first to follow the local inquiries of these Commissioners, who, in a Report signed by their Chairman, have said that experience in every country has proved that the yield of gold decreases with the depth, after a certain small limit, when mining in the solid rock had been attempted. An enumeration by name was indeed made of ten working shafts which had been abandoned in consequence of finding the gold diminish downwards,—in some cases at a few feet only, in others ceasing entirely, and again in a third class continuing downwards in small quantities to about 300 feet. They then concluded, that enough has been stated to vindicate the scientific inference that deep mining in the solid quartz rock is usually unprofitable,—a conclusion which was in unison with my opinion founded on knowledge derived from other gold countries, as published many years before gold was worked in Victoria: this was reiterated in the first edition of 'Siluria.'

The knowledge, however, which I have since obtained, induces me materially to modify that view, and particularly as respects the colony of Victoria. Through the consideration of Lord Stanley, when recently H.M. Secretary for the Colonies, I was made acquainted with the opinion of Sir H. Barkly, the enlightened Governor of the colony, as based upon extensive inquiries and personal observation, which went to show that

* See Report to the Surveyor General and the Chief Secretary on the Mining Resources of the Colony of Victoria, 1856–7.

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a much greater supply was derived from mining in the "quartz reefs" than I had supposed to be the case. Again, H. M. present Secretary for the Colonies, Sir E. Bulwer Lytton, having transmitted to me, through the Earl of Carnarvon, copies of the most recent despatches (July 12) from Sir H. Barkly, with Reports from Mr. Selwyn, accompanied by coloured geological maps and sections prepared by that able geologist, whose observations extend over more than five years,—I am bound to say that, if the quartz-reefs yet untouched should prove as rich as several which are now yielding good profit to the miner, the future supply of gold from Victoria will be much more durable than that derived from any other known auriferous country, excepting perhaps a portion of California. In fact, Victoria is, as far as I know, the richest gold country of which history records an example, whether we look to the very wide diffusion of the auriferous debris, which Mr. Selwyn estimates to be spread over 10,000 square miles, or to the quartz veins in the solid slaty rocks, which, by the improved processes of crushing, are forced to yield a supply which could not have been obtained a few years ago by any of the old methods of extraction (see note, p. 479).

Mr. Selwyn has satisfied himself that the gold quartz veins of Victoria are confined to rocks of the Lower Paleozoic age, chiefly those which belong to my original Lower Silurian division in ascending from the Llandeilo formation to the Upper Caradoc inclusive, or those strata charged with Pentameri, which in this volume are termed Llandovery rocks. "In every part of the colony," says he, "where such rocks appear on the surface, they are intersected almost invariably in a meridional direction by quartz veins, from the thickness of a thread to the dimensions of 10 or 15 feet, and in marvellous abundance. Not one per cent. of these 'quartz reefs' has as yet been touched by the miner, and therefore the only evidence we have at present of their containing gold is in the richly auriferous and widely-spread tertiary deposits [drifts] which everywhere accompany them, and which have undoubtedly been derived from their pre-existing upper surfaces."

After showing that the vast areas of granite which in this region have been protruded through those old stratified auriferous rocks, have had no influence upon their meridional or north and south direction, or their upheaval and contortion, this skilful observer infers, that the quartz veins of the Silurian rocks of Victoria are older than the granites.

Believing that the cracks and fissures in which the gold quartz reefs occur have not been mineralized by any process different from that which has operated in other mineral veinstones, he remarks, that "although no very reliable evidence exists of their increasing downwards very greatly in richness, neither is there any evidence whatever in Victoria which would enable us to state, that any vein rich at the surface will die out or suddenly become unprofitable."

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"There is undoubtedly good evidence," he adds, "that those upper portions of the gold quartz veins which have been naturally removed by denudation, and now form the gold drifts, were often far richer than any we now find at the surface; but in drawing conclusions from this evidence, we should not forget, that in all probability many hundreds of vertical feet of quartz veins have been thus naturally broken up, crushed, and washed; and the fact of the veins (so abraded) being still frequently very rich on their present surface, goes far, I think, to prove that the diminution of yield in depth, even though admitted to be true on a large scale, is still so slow as not to be appreciable within any depth to which ordinary mining operations are carried."

Giving several illustrations confirmatory of his views, and showing that the deepest shaft in which a quartz vein was proved productive reaches to 400 feet, Mr. Selwyn concludes by expressing his opinion, "that the extraction of gold from quartz reefs, if properly conducted, may be regarded as an occupation which will prove as permanently profitable in Victoria, as tin* and copper mining have been in Great Britain."

In bowing to the reasoning of a sound geologist, who has so carefully explored our most auriferous colony, and in necessarily modifying my former suggestion respecting the profitless nature of gold-mining *in the solid rocks of Victoria*, I still adhere to the belief, that, in general, gold-veins diminish in value as they descend; and I cannot but think that even Victoria affords indications of this phenomenon, inasmuch as all the huge nuggets of gold have there been found in drift derived from the upper portion of the rocks. I have indeed yet to learn, that lumps of gold approaching to large dimensions have been detected in any one of the numerous quartz reefs which are now worked in California or Victoria; in these the gold is disseminated downwards in fine strings or small grains†.

* It may also be here mentioned, that the gold-fields of Victoria have afforded tin, a mineral unknown in Russia, which is found not only in the form of sand, but also in small lumps, and highly coloured crystals. The reader who wishes to obtain a general view of the most important of the Australian gold diggings, and acquire an insight into the statistics and social condition of the wonderful colony of Victoria, should peruse the works of Mr. Westgarth and Mr. Wathen. As regards produce up to a certain period, see also Delesse, Annales des Mines, 1853, tom. iii. ser. 5. p. 185. The true chronicler, however, of all the auriferous returns must refer to the files of the Victorian newspapers. By the Melbourne 'Argus' of July 15th, I learn that the yield of gold, which in 1857 had diminished, has during the first six months of the present year (1858) exceeded the average of former years. In showing a steadiness of produce which gives promise of years of prosperity to come, we also learn, from a valuable and instructive table in the same journal, that the produce of gold has by no means kept pace with the increase of the population, which now amounts to nearly half a million of souls. Thus, in the second year of gold extraction (1852) the amount was 1,974,975 ozs., with a population of 148,000 persons; whilst in 1857 the yield did not exceed 2,729,655 ozs., with a census of 457,000 inhabitants. It is a fact well worthy of notice, that in 1857, 62,236 persons were engaged in mining pursuits; and that, although the population has augmented in this year, the number of miners has by the last accounts decreased.

† Since the large lump, weighing upwards of 146 lbs., called the 'Blanch Barkly Nugget' (see note, p. 484), was exhumed, another mass has, it is said, been

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One of the most striking examples of successful mining in quartz reefs is given in a recent Report of Mr. Selwyn upon the Clunes quartz-mining-field, about twenty miles north of Ballaarat, and in the occupation of the Port Phillip Company. There, it appears that four thin quartz veins, trending from north to south, and running parallel to each other and to the strata, plunge eastwards in conformity with the strata of the Lower Silurian rock in which they lie, and at a high angle near the side of a hill, so that the small width of the veined ground, from west to east, is easily traversed by adits from the lower sloping side of the hill. An abundance of water, and every facility for working by means of levels, together with the position of the veins, present a combination of circumstances, as Mr. Selwyn observes, rarely met with in connexion with quartz veins, and one which will enable these reefs to be worked far more profitably, and at greater depths, than many others in the colony of Victoria*.

In thus modifying a portion of my views, I readily admit, that inasmuch as the broken or drift gold of Victoria has exceeded anything of which we have a record in history, so it is a fair inference, that the quartz reefs in the solid rock of the same colony, from the higher parts of which the richest drifted materials were derived, may prove much more remunerative than those of other countries.

Looking, however, at the Australian phenomena on a broad scale, there are no essential distinctions between them and the geological relations of gold in the Old World and in America.

The great sources of wealth, as elsewhere, are those depressions which have been filled, or slopes which have been strewed over, with debris from the mountains, whether coarse or fine. The outlines and depths of all these detrital heaps are ascertainable, and the period of their exhaustion may therefore be estimated approximately. It matters nothing to the statist whether the richest portions of this golden drift, or accumulation of broken materials, were for the most part aggregated, as I think, by causes now no longer in action, which powerfully abraded the surface of the hills (as explained in the previous pages, and parti-

found at Ballaarat, weighing more than 184 lbs.! Now, as these and all the large nuggets occur low down in drifts, the facts seem strikingly to confirm my view, that the higher portions of the veinstones, or those first abraded, afforded masses of gold much larger and richer than those finer filaments and grains which, derived from *lower* parts of the veinstone, are lodged in the *upper* detritus.

* In his Report on this mine, Mr. Selwyn offers the surmise, that, as a former covering, of great thickness of strata, has been removed, and the broken materials distributed in the drift occupying the slopes and valleys of Victoria, the gold quartz reefs now exposed on the tops of the depressions are those portions of the veins which originally were at great depths. If this view be fully admitted, the speculator in Victoria who sinks for gold in the solid rock has certainly in it an argument in his favour. Judging, however, from facts and experience, it may still be affirmed that gold has not yet been found to expand downwards, like copper and lead; such a phenomenon being as yet unknown in any country.

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cularly in the diagram, p. 489), or whether the diurnal atmospheric action for thousands of years has also been an effective agent. Both causes have unquestionably contributed to spread out and render more accessible a material, the search after which in the solid rock is attended with so much difficulty.

In the mean time, a basis of all such researches and inquiries into the probable amount of the drift gold, must be provided by good geographical surveys of the auriferous countries of Australia, as completing the work commenced by the late Sir T. Mitchell and his associates. On that important groundwork, geologists may record all progressive observations respecting a region hitherto almost exclusively pastoral, but which has suddenly become a great and populous centre of commerce through the development of its very prolific gold-fields*.

Conclusion.—Notwithstanding the preceding sketch, it would ill become any geologist, who throws his eye over the gold map of the world prepared by Adolf Erman, to attempt to estimate, at this day, the amount of gold which remains, like that of Australia, undetected in vast regions of the earth, as yet unknown even to geographers; still less to speculate upon the relative proportions of it in such countries. At the same time, the broad features of the case in all known lands may be appealed to, to check extravagant fears and apprehensions respecting an excessive production of the ore; for we can trace the boundaries, rude as they may be, of a metal ever destined to remain precious on account of those limits in position, breadth, and depth by which it is circumscribed in Nature's bank. Let it be borne in mind, that, whilst no quantity of gold has ever been found in veins in the secondary and tertiary rocks which occupy so large a portion of the surface, mines sunk down into the veinstones of the old slaty rocks, where it does occur, have hitherto, with rare exceptions (chiefly in Victoria), proved unremunerative. The other cases, in which deep mining repays, are

* In this chapter I necessarily abstain from alluding to many tracts more or less auriferous, but not yet known to be *rich* in produce, which come under the same laws of distribution as those described in the text. Such, for example, are the phenomena of the southern provinces of the United States (S. Carolina, &c.), and also of the British province of Canada, whence a certain amount of gold has been derived from metamorphic rocks, which, according to Mr. Logan, are probably of Lower Silurian age. The discovery of gold on the Frazer River, in the western possessions of British America, was quite to have been expected, as the ridges between which that river flows are simply prolongations of the auriferous chains of California, which are (in great part, at least) of Lower Silurian age. That a large portion of the Rocky Mountains, both British and Russian, will prove to be auriferous, is indeed to be inferred by the recent discovery on the Frazer River.—*July* 1858.

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those where the rocks are soft, and the price of labour low. Further, it has been ascertained, that, whatever may have been the agency by which this impregnation was effected, the metal has been chiefly gathered together in veinstones towards the surface of the rocks; and then, by the abrasion and dispersion of these parts, the richest golden materials have been spread out, in limited patches, and generally near the bottom of basin-shaped accumulations of detritus.

Now, as every heap of these broken auriferous materials in foreign lands has just as well-defined a base as each gravel-patch in our own country, it is quite certain, that hollows or slopes so occupied, whether in California or Australia, must be dug out and exhausted, in a greater or less period. In fact, all similar deposits in the Old or New World have had their gold abstracted from heaps the areas of which have been traced, and their bottoms reached. Not proceeding beyond the evidences registered in the stone-book of Nature, it may therefore be affirmed, that the period of such exhaustion in each country (for the deposits are much shallower in some tracts than in others) will, in great measure, depend on the numbers and activity of the workmen employed in each locality. Numerous hands, used with Anglo-Saxon energy, in California and Australia, may, in a quarter of a century, accomplish results which could be attained only in many centuries by a scanty and lazy indigenous population; and thus the present large flow of gold into Europe from such tracts must, in my opinion, diminish, as soon as the richer detritus of certain tracts has been sifted.

In defining the general character of the most productive auriferous rocks, the geologist must, however, necessarily admit a considerable number of exceptions to any prevailing rule; for, whilst the chemist, as before said, has recently detected minute traces of gold in lead and copper ores, the researches of the practical miner have taught us, that in any auriferous region where certain quartzose lodes are surcharged with ores of iron, particularly the oxides and sulphurets, *some* amount of gold will probably be found. Again, the diffusion or dissemination of small particles of gold throughout the body of various rocks both of igneous and aqueous origin, is, as before said, a phenomenon dwelt upon by certain authors. Humboldt, indeed, asserted long since, that in Guiana, "gold, like tin, is sometimes disseminated in an almost imperceptible

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manner in the mass itself of the granitic rocks, without the ramification or interlacing of any small veins*." In Mexico, the gold mine of Guadalupe y Calvo, before alluded to†, was in porphyry. In Australia (district of Braidwood, and others south of Sydney), a peculiar variety of felspathic granite is described by Mr. Clarke as being permeated by small particles of gold; whilst in Siberia, Hoffmann, as already stated (p. 487), had spoken of its distribution in such minute quantities in clay-slate, that it was only by pounding up large lumps of the rock that any perceptible quantity could be extracted‡.

In all regions, therefore, where auriferous rocks occur, we may find gold either in the coarse debris of tertiary age, or in the fine modern alluvia resulting from their decomposition. Felspar and quartz being their chief component parts, we can easily imagine how their former destruction on a great scale would leave as a residue large heaps of that pipe-clay (the decomposed felspar), or those gritty pebbles (the abraded quartz), which, with the accompanying ores of iron (particularly the black magnetic oxide), are so frequently the gold-bearing matrices in the drift of auriferous countries. But whilst it is an admitted fact, that gold has sometimes been so diffused in minute and imperceptible particles in certain rocks, we know of no case, I repeat, in which, when it has been segregated into lumps and veins, the ore ever expands downwards in the body of any mountain. At all events, the indisputable fact is, that the *chief quantities of gold,* including all the considerable lumps and pepitas, have been found imbedded in the *upper parts of the veinstones,* and have been broken up and transported with the debris of the mountain-tops on slopes or into adjacent valleys.

In closing these remarks, let me express my opinion, that the fear that gold may be greatly depreciated in value relative to silver—a fear which may have seized upon the minds of some of my readers —seems to me to be unwarranted by the data registered in the crust of the earth; for, after all the recent discoveries, my readers may be assured that gold is much the most restricted—in its native distribution—of the precious metals. Argentiferous lead, on the contrary, expands so largely downwards into the bowels of the rocks,

* Voyages, vol. ii. p. 238. † Page 488.

‡ Reise nach dem Goldwäschen Ost-Sibiriens by Ernst Hoffmann, St. Petersburg, 1847.

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as to lead us to believe that it must yield enormous quantities of silver for ages to come; and the more so in proportion as better machinery and new inventions shall lessen the difficulty of subterranean mining*. It may indeed well be doubted whether the quantities both of gold and silver procured from regions unknown to our progenitors will prove more than sufficient to meet the exigencies of an enormously increased population and our augmenting commerce and luxury. But this is not a theme for a geologist; and I would simply say, that Providence seems to have originally adjusted the relative value of these two precious metals for the use of man, and that their relations having remained the same for ages, will long survive all theories. Modern science, therefore, instead of contradicting, only confirms the truth of the aphorism of the patriarch Job, which thus shadowed forth the downward persistence of the one and the superficial distribution of the other:—"Surely there is *a vein* for the silver . . . . . The earth hath *dust of gold*†."

This great truth being sustained by the experience of ages, the geologist further shows, that the stony masses which have supplied this dust (or drift) of gold, as now distributed over the surface, are chiefly those Silurian or associated rocks which have been the especial subject of our consideration.

* A Report from the late Col. Lloyd (Journ. R. Geograph. Soc. vol. xxiii. p. 196) showed to what a vast extent silver might yet be extracted from the South American mines. This was, indeed, the view taken long ago by Humboldt, who has expressed to me his conviction that the produce of silver will be much augmented, reminding me how tracts in Spain which contained rich silver-mines in the days of Hannibal had recently proved to be highly productive.

† The Book of Job, chap. 28.

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CHAPTER XX.

RECAPITULATION.—SILURIAN ROCKS OF THE CONTINENT COMPARED WITH THOSE OF BRITAIN.—GENERAL VIEW OF THE SUCCESSION OF LIFE FROM ITS FIRST RECOGNIZABLE TRACES.—THE PROGRESS OF CREATION FROM AN INVERTEBRATE EPOCH THROUGH SUCCESSIVE PERIODS; THE FIRST MARKED BY THE ADDITION OF FISHES, THE NEXT BY THAT OF REPTILES, AND THE THIRD BY THAT OF MAMMALS.—THEORETICAL SPECULATIONS DISTINGUISHED FROM ABSOLUTE GEOLOGICAL RESULTS.—CONCLUSION.

REVERTING to the main object of this work,—the history of the primeval rocks,—let us now see what inferences may be drawn from data furnished by the researches of the geologist. Passing rapidly over the earliest stages of the planet, which are necessarily involved in obscurity, our sketch of ancient nature began with the first attainable evidences of the formation of sediments composed of mud, sand, and pebbles, which overlie the fundamental ancient gneiss* of Britain and other countries. It was shown, that the lowest of these regenerated deposits, though of vast dimensions, and occasionally less altered than some of the strata formed after them, contained the rarest trace of inhabitants of the seas in which they were accumulated.

Proofs were then adduced to demonstrate that in the next formations, little differing in mineral character from those which preceded them, observers in various regions had detected clear but scanty signs of a contemporaneous appearance of animal life, as shown by the presence of some few crustaceans, mollusks, and zoophytes, occupying layers at a similar horizon in the crust of the earth in very distant regions. Proceeding upwards from that early zone, we then ascended to other sediments, in which we recognize a copious distribution of submarine creatures, closely resembling each other, though imbedded in rocks now separated by wide seas, and occasionally raised up into high mountains, as in the Himalayan region. Examining all the strata exposed to view, that were formed during the first long natural epoch of similar life termed Silurian, we found that the successive deposits were charged with

* See Appendix B.

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a great variety of forms,—of the trilobite, a peculiar crustacean,—of the earliest chambered shells,—as well as with numerous exquisitely formed mollusks, crinoids, and zoophytes; the families of cystideans and graptolites being exclusively found in these Silurian rocks. In short, my contemporaries have assembled, from those ancient and desiccated sediments or repositories of primeval marine creatures, examples of every group of purely aquatic animals, save fishes. Though we are now as well acquainted with the contents of the paleozoic rocks as with those of mesozoic age, the multiplied researches* during the last twenty-five years have failed to detect the trace of a fish, amid the multitudes of all other marine beings, in the various sediments which constitute the mass of the Silurian rocks. Of these, though they are the lowest in the scale of the great division Vertebrata, we are unable to perceive a vestige until we reach the highest zone of the Upper Silurian, and are about to enter upon the Devonian period. Even on that horizon, the minute fossil fishes, long ago noticed by myself, are exceedingly scarce in Britain, though more abundant in Russia. In fact, the few cartilaginous ichthyolites of the uppermost band of Silurian rock still remain the most ancient known beings of their class†. (See Pl. 35.)

Looking, therefore, at the Silurian System as a whole, and judging from the collection of facts gathered from all quarters of the globe, we know that its chief deposits (certainly all the lower and by far the thickest and most extensive) were formed during a long period, in which, while the sea abounded with countless invertebrate animals, so far as is known, no bony fishes had been called into existence‡. The Silurian (except at its close) was consequently an epoch in which there appeared no example of that complete bony framework, in which, as approaching to the vertebrate archetype, the comparative anatomist§ traces the first step in that series of creations which ended in Man.

* My researches were commenced in 1831, and the Silurian classification was propounded in 1835.

† I do not admit that the microscopic Russian forms called Conodonts by Pander belong to fishes. See Prof. Quekett's note on this point (Appendix F).

‡ See Appendix G for the correction of the mistake of the supposed existence of vertebrata in the Silurian rocks of the W. of France!

§ See Owen on the Homology of the Vertebrate Skeleton, Reports Brit. Assoc. Adv. Science, 1846, p. 169. The general reader will find a powerful essay, embodying the opinions, I believe, of the same high authority, on the proofs of a progression in creation, in the Quarterly Review, 1851,

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Whether, therefore, the term "successive" or "progressive" be applied to such phenomena, I maintain, upon sound and general evidence, that there was a long period in the history of the world wherein no vertebrated animal seems to have lived. In this sense, the appearance of the first recognizable fossil fishes, towards the close of the Silurian period (and then they were cartilaginous), seems to be as decisive a proof of a distinct creation, as the placing of Man upon the terrestrial surface, at the end of the whole list of animals which characterize the younger geological periods.

Nor have we been able to disinter from the older strata of this long period of invertebrate life, any distinct fragments of land-plants. But in the very same stratum wherein the few earliest small fishes have been detected, there also have we observed the first clear appearances of trees, also of very small dimensions.

If it be granted that the position of the earliest recognizable vertebrata is sound evidence on which to argue, still it may be contended, that such forms might at a future period be found in still lower strata. In this work, however, I reason from known data only. Nor is it on such testimony alone, strong, clear, and universal as it is, that my argument is based; for as soon as we pass into the formation immediately overlying, and quit the zone wherein the first few fishes have been detected, we are furnished with collateral proofs that this was the earliest great step in a successive order of creation. In the following or Devonian period, we are surrounded by a profusion of large fossil fishes, with vertebræ rarely ossified*, and with dermal skeletons of very singular forms —all differing vastly from anything of their class in the succeeding epochs. It is thus clear that these fishes were marked additions to the pre-existing forms of marine life. Again, in this Devonian era, we are presented with some well-defined land-plants, also of larger dimensions than the rare specimens in the uppermost Silurian; while, towards the close of the period, we meet with an air-breathing reptile. With the little Telerpeton there were some tree-

p. 412 *et seq.* The arguments there employed have been strengthened by subsequent discoveries alluded to in this volume. I would also specially refer the reader to Professor Sedgwick's 'Discourse on the Studies of the University of Cambridge' for a masterly and eloquent illustration of several of the views which are here advocated.

* A Coccosteus with a true bony vertebra has recently been found by Mr. C. Peach, and added to the Museum in Jermyn Street.

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ferns, or at least lycopodiaceous plants, and even Coniferæ, amid the roots of which he could nestle (see p. 290).

But this lizard was not solitary; for in my last excursion to the North of Scotland (September 1858) I satisfied myself that this little animal had a larger associate in the youngest member of the Devonian series,—the footprints of a large reptile being rife on the surface of the sandstone N. of Elgin*, which I am convinced is of Upper Devonian age; whilst even its bones—still retaining the osseous matter—have been preserved in the body of the yellowish sandstone rock. (See Appendix B and Q.)

Just as the introduction of cartilaginous fishes is barely traceable towards the close of the long Silurian era, so, becoming afterwards much more abundant in the Devonian rocks, they are thenceforward associated in all younger formations with true osseous fishes and lacertian reptiles, the remains of which are found intermixed with the other exuviæ of the sea.

Putting aside theory, therefore, and judging solely from very numerous and extensive observations, we may still fairly infer, first, that during very long epochs the seas were unoccupied by fishes; secondly, that the earliest discoverable creatures of this class had very rarely an internal vertebral osseous column; and thirdly, that in the succeeding period, the fishes having bony vertebræ, appearing in greater numbers, became abundant in the overlying deposits. Do not these absolute data of the geologist, resulting as they do from the most minute as well as the most general researches, afford clear signs, in this respect, of a progress in creation?

In the Silurian era, as will presently be insisted on, there are countless proofs of shores, and yet not a trace of a land-plant washed from the adjacent lands until we reach the uppermost limits of the system. The signs of terrestrial produce, augmenting in the Devonian epoch, become abundant in the Carboniferous period, as marked by the first copious and terrestrial flora. This earliest luxuriant tree-vegetation, the pabulum of our coal-fields, is also specially remarkable for its spread over many latitudes and longitudes; and together with it occur the *same common species* of marine shells, all indicating a more or less equable climate from polar to intertropical

* For the first mention of footprints of a reptile larger than the Telerpeton in these rocks, see Brickenden, Quart. Journ. Geol. Soc. vol. viii. p. 37. pl. 3.

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regions,—a phenomenon wholly at variance with the present distribution of animal and vegetable life over the surface of the planet. And with the earliest profuse land-vegetation, large reptiles, which first appear in the Upper Devonian, augment in numbers, and add to the proofs of a rise in creation.

Lastly, while the Permian era was distinguished by the disappearance of the greater number of the primeval types, and by essential modifications of those which remained, it still bore a strong resemblance, through the genera of its plants and animals, to the Carboniferous period; whilst, in unison with all the great facts elicited by our survey of the older strata, it was typified by the appearance of an animal of a higher grade than any one in the foregone eras—the Protorosaurus, a large thecodont reptile, allied (according to Owen) to the living Monitor.

In speaking of the Silurian, Devonian, Carboniferous, and Permian rocks, let me however repeat, that, whilst each of the three latter groups occupies wide spaces in certain regions, no one of them, except the Carboniferous, approaches to the value of the Silurian, in representing time, or the succession of animal life in the crust of the globe. When the Silurian system was divided into lower and upper parts, our acquaintance with younger formations merely sufficed to show a complete distinction between its fauna and that of the Carboniferous rocks, from which it is separated by the thick accumulations of the Old Red Sandstone. At that period, the shelly, slaty rocks of Devonshire were not known to be the equivalents of such Old Red Sandstone; still less had the relations and fossil contents of all the strata now called Permian been ascertained. Judging from the fossils then collected, it was stated by me that the Lower Silurian contained organic remains very distinct from those of the Upper Silurian; and yet I united the two groups in a system, because they were characterized throughout by a common *facies*. This so-called system was, in short, characterized by a profusion of Trilobites and Graptolites, with Orthides and Pentameri of a type wholly unknown in the Carboniferous rocks: and, whilst fishes were seen to exist in the intermediate masses of Old Red Sandstone, no traces of them could be detected below the very uppermost zone of the Silurian rocks. A quarter of a century has elapsed, and, after the most vigilant and detailed researches in

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various regions of both hemispheres, these great features remain the same as when first indicated. The labours, however, of those who followed me have infinitely more sustained the unity of that system*; for its lower and upper divisions are now proved to be connected, not only by such generic types and analogous forms, but, further, by the community of a very considerable number of identical bodies.

Let me here, therefore, and before the superior formations are further spoken of, recall attention to the fourteenth and fifteenth chapters, on Scandinavia, Russia, and Germany, in which it has been shown, on the authorities of de Verneuil, von Keyserling, Barrande, Kjerulf, Schmidt, and others, that the Lower and Upper Silurian rocks of those countries constitute one natural *system*. On this head I beg further to explain by citing my own words, as used at the conclusion of a memoir on this subject, read last year before the Geological Society of London†:—

"In the opening pages of this memoir a running comparison was instituted between the different subformations which constitute the Silurian basin of Christiania in Norway and their British equivalents; and, considering the distance of the Norwegian tract from our own country, the coincidence in the succession of fossils is truly remarkable.

"The point, however, of the labours of M. Kjerulf to which I now particularly recall attention, is that in the very lowest fossiliferous zone (the alum-slates of Norway) the types of Trilobites (Olenus and Agnostus) which were supposed by some authors to be confined to that zone are united with the Orthis calligramma and the Didymograpsus geminus, species known to occur in unquestionable Lower Silurian British rocks. Any one of the published sections across the western parts of Shropshire, *i. e.* from the Longmynd over the Stiper Stones, shows what the parallel order is in Britain‡.

"Having for the last twenty-four years considered and described the Stiper Stones as the true physical base of the Silurian series of strata, it

* See the works of John Phillips, E. de Verneuil, Edward Forbes, Joachim Barrande, James De C. Sowerby, James Hall, J. W. Salter, D. Sharpe, T. Davidson, and John Morris. The most recent researches in Britain give the large number of nearly 100 species of fossils common to the Lower and Upper Silurian. (See also the Preface, and the Table in Appendix A.)

† See the memoir "on the Silurian Rocks and Fossils of Norway, by Theodor Kjerulf, and of the Baltic Provinces of Russia, by Professor Schmidt, compared with their British equivalents;" Quart. Journ. Geol. Soc. vol. xiv. p. 36 (1857). Since that publication, and as these last lines are printing, I have received Professor Schmidt's published work, for which consult the Appendix (I).

‡ See the 'Silurian System,' pl. 32. f. 1, &c., and 'Siluria,' 1st edition, diagram, p. 29.

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has been satisfactory to me to detect recently, in the black schists associated with the siliceous flagstones of that ridge, additional fossils which so intimately connect them with the Llandeilo formation, that the additional evidence in the new edition of 'Siluria' (see Chapter 3) will, I believe, be conclusive as to the natural base of the British Silurian rocks; for neither in Shropshire nor in Norway can we draw a line of physical or zoological demarcation between these basement-strata, whether termed Lingula Flags, Stiper Stones, or Alum Slates, and those overlying schists into which they graduate, and of which they form an integral part. This union is indeed particularly well marked in Scandinavia, where the alum-slates are simply a mass of black schist, which is no more capable of separation from the overlying beds of similar characters than one bed of the Lower Lias or any other secondary shaly subformation is from another* (pp. 368 *et seq.*).

"Seeing the dissimilarity of forms which prevails throughout the Silurian series of Bohemia, as described by M. Barrande, when we look to the distinction between the fossils of each of the subdivisions, and especially when we compare such subdivisions with their acknowledged equivalents in the northern Silurian zone now under consideration, it seems to me to be impossible to establish a new classification of the Lower Paleozoic rocks by eliminating the 'Zone Primordiale' of that distinguished author from the natural-history system in which he has himself placed it. In Bohemia the 'Zone Primordiale' is as integral a part of the Silurian basin so called, as the Stiper Stones were in my original classification. If I am not justified in referring to my sections and memoirs of the years 1833 and 1834, when I classed the Stiper Stones with the overlying deposits, I am at all events entitled to adhere to that view, now that M. Barrande also unites his 'Zone Primordiale' with the overlying strata, and since, fully aware of the distinction between its fossils and those which succeeded it in Bohemia, this eminent geologist continues to classify it with the Silurian system.

"We all know how, in those secondary and tertiary rocks which have been most examined, there is often a marked discrepancy in the fossils of each succeeding stratum, *so long as we examine a limited area only*, and how such sharp separation and isolation of the former inhabitants of the seas vanish when the same strata are followed over great distances. So is it when, quitting our insular area and extending our researches to Norway, we find strata of black schist, mineralogically

* M. de Verneuil has recently discovered at St. Léonhard (Department of La Sarthe, S.W. of France) that siliceous beds, charged with Lingulæ, there also underlie trilobitic slates of Llandeilo age, and constitute, as in Norway, Britain, and Canada, the actual base of the fossiliferous Lower Silurian rocks. The ensiform bodies occurring in these trilobite-slates, and supposed by M. Marie Roualt to be ichthyolites, have not the least relation to vertebrata, or anything of higher order than Fucoids possibly. See Appendix G, and Comptes Rendus de l'Acad. vol. xlvii. p. 469.—*Nov.* 1, 1858.

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resembling the Lingula-flags or the schists of the Stiper Stones, and occupying the same place in the geological series, to be charged with some of the organic remains which in Britain are peculiar to that band, mixed up with species which are known in our own Llandeilo rocks. Again, we observe that, as in the Stiper Stones of Shropshire, there is in Norway a vast underlying series of slates and quartzose rocks like those of the Longmynd; so also are the beds into which the alum-schists pass *upwards* laden with many species of fossils which are with us in the Lower Silurian rocks of Llandeilo age.

"The attempt to separate the alum-schists of Scandinavia from the overlying beds with which they are united in numerous natural escarpments is indeed forbidden on stratigraphical, lithological, and zoological grounds; and as Linnæus and every subsequent explorer of Scandinavia have connected them, so I confide in the belief that they constitute, by their organic remains, the best base we have been able to trace of that which I call Silurian life.

"In comparing the Silurian rocks of Scandinavia and Russia with those of Britain, there is no feature by which the whole system is seen to be better characterized in those countries than by containing in its central part a formation distinguished from the rocks above and below it by certain species of Pentameri, of which the Pentamerus oblongus and the P. lens are the prevailing types.

"Having satisfied myself, in my own country, that the lower portion of this formation is (as I always maintained) related by its organic remains to the Caradoc formation, and that the upper part of it is charged with a number of shells of the Wenlock age (though still intermixed with the peculiar Pentameri and a few Lower Silurian fossils), I have deemed it right to assign to the deposit a separate and intermediate place in the table of Silurian strata.

"I have named this formation 'Llandovery rocks,' reverting to that tract of South Wales which was originally described in detail, and where both the lower and upper members of the group, and their relations to the underlying and superjacent rocks, are clearly exhibited.

"It is the upper member only of these Pentamerus-rocks which is exhibited at May Hill, on the west flank of the Malverns, and also in the typical Silurian tracts of Shropshire, Herefordshire, and Radnorshire. This upper band only is the May Hill Sandstone*.

"In parts of South Wales, where both members of the Llandovery rocks exist, there is usually, indeed (but in my opinion not always), a transgression between them, as traced by Professor Ramsay and Mr. Aveline,—the lower member constituting over large areas the regular

* See Proc. Geol. Soc. vol. ii. p. 13; Sil. Syst. p. 442. pl. 36. f. 13; Sedgwick and M'Coy, Quart. Journ. Geol. Soc. vol. ix. p. 215; and Phil. Mag. 4th ser. vol. viii. p. 301, &c.

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capping of the Caradoc or Bala formation, the upper or May Hill rock appearing to be usually the symmetrical base (as in Siluria proper) of the Upper Silurian group. As, however, the same species of Pentamerus, Atrypa, and Petraia, &c., occur in both these divisions, I am induced by this community of type, and by the opinion of Mr. Salter, to consider the two bands as forming one natural-history province which connects the fauna of the Lower and Upper Silurian groups. Now, if we refer to certain other regions, the truthfulness of this view is strikingly confirmed, since in them we can detect no such transgression or hiatus as occurs in Wales and the border-counties of England.

"Even in the neighbourhood of Girvan, in Scotland, fossiliferous Lower Silurian rocks of the Caradoc age seem to graduate upwards conformably into the Pentamerus-zone in question, containing not only the P. oblongus in profusion, but also the Atrypa hemisphærica, with the Phacops Stokesii of the Wenlock limestone, and thus leaving no doubt that we have there reached, as I formerly showed, the base of the Upper Silurian rocks*. In Norway, however, where the area under consideration is much smaller†, and where all the Silurian strata are [united and] clearly exposed in numerous convolutions in islets of the Bay of Christiania, there is, independently of all breaks caused by the intrusion of igneous rocks, a perfectly conformable succession from the Lower to the Upper Silurian‡. There, as in Esthonia, the Pentamerus-zone is simply the central link of an unbroken Silurian chain,—so local is the physical disturbance in the Welsh region seen to be, when the whole surface of Northern Europe is explored.

"Whilst the Norwegian and Swedish sections are so valuable in showing the base of the System, the Esthonian order of the fossiliferous strata is highly instructive in demonstrating the accordance of the Upper Silurian rocks with our own. The observations of M. Fr. Schmidt are, indeed, most valuable in placing before us, for the first time, a complete exposition of all the natural subdivisions of the Silurian series of so large a part of European Russia. In Esthonia, the approximation to the British succession, from the Llandeilo formation to the summit of the Upper Silurian, is very remarkable. Just as in Norway, England, and America, so in Esthonia the transition-zone from the Lower to the Upper Silurian is the deposit laden with Pentameri, to which the name of Llandovery rocks has been assigned, because it was long ago described by me at and around the town of Llandovery in South Wales. Whilst the Wenlock fauna is quite recognizable in Esthonia, as in Norway, the fossils of the highest zone of the former country, including

* Quart. Journ. Geol. Soc. vol. vii. p. 149.

† An accidental erratum occurs in the letter-press of the Quart. Journ. Geol. Soc. vol. xiv. p. 51:—*for* "much larger" *read* "much smaller."

‡ See the diagram-section across the Territory of Christiania, Quart. Journ. Geol. Soc. vol. viii. p. 182.

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many large crustaceans (Eurypteridæ), with Lingula cornea and Trochus helicites, are strikingly characteristic of the Ludlow rocks.

"Such agreement between those remote foreign rocks and our strata of the same age is the more remarkable, when we consider the difference in thickness and the simplicity of lithological characters of the deposits in these northern countries, as compared with the vastly extended British types. The thousands of feet of diversified British Silurian rocks, whether slates, schists, shales, conglomerates, sandstones, quartz-rocks, limestones, mudstones, with vast sheets of interstratified igneous rocks, are represented in the Baltic provinces of Russia by little more than one lithological character only. There, they are all closely united calcareous masses, any one of which has so great a resemblance to another, that, without the aid of Paleontology, they could never be separated or distinguished. The united Lower and Upper Silurian constitute, in fact, to use the language of Count Keyserling, 'but a single volume of limestone of small capacity and thickness, capable of division into leaves by that person only who is acquainted with their included fossils;' the whole series not exceeding 2000 feet, and all the strata graduating into each other by conformity of deposition.

"The interest, however, which attaches to the full illustration of these Northern European types of the oldest known fossiliferous rocks, does not terminate with the precise comparison between them and the British contemporary formations*.

"The same species, even, are found to prevail far to the westward in northern latitudes. Small as are the deposits, in vertical dimensions, both of Scandinavia and Russia, the very same succession of life which they offer is found to be persistent from those countries across the British Isles to the heart of North America. The vastly extended Lower Silurian rocks of the United States and Canada, and the enormously spread Upper Silurian of the Arctic Regions, are, like those of our own country, the absolute historical equivalents in time of the thin and simple series described on this occasion, and exhibit a vast number of forms specifically identical with those I have enumerated.

"Other species, however, of Silurian typical genera prevail throughout the southern region of Europe†. Already we know that the Silurian rocks of France and Spain, as illustrated and compared by my distinguished associate, de Verneuil, have, however, many specific equivalents in the Lower Silurian rocks of that Bohemian basin which has been rendered classic through the works of M. Barrande.

"Count Keyserling further recalls my attention to the fact, that the

* It is true, that in Russia there are fewer British species than in Sweden and Norway, but this is just what we might expect from the relative distances of those lands from our own country.

† With additional researches, may not this Silurian type of Southern Europe and Siberia be found to have its equivalents in the central and southern parts of America?

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Ural Mountains and Siberia fall into the same category. This comparison, which was to some extent shadowed forth in the work 'Russia and the Ural Mountains,' published in 1845, has been strikingly confirmed by the researches of M. Grünewaldt into the characters of the fossils of the eastern flank of the Ural Mountains near Bogoslofsk (lat. 61°). Again, M. Hoffmann concludes his Siberian work in terms which show, that the parallel was suggested eleven years ago by Keyserling, as a result of his researches and comparisons in the Northern Ural. In short, my coadjutor long ago directed notice to the fact, that, both in paleontological contents and lithological characters, the Silurian rocks on the eastern side of the Ural Mountains were dissimilar to those of European Russia and Scandinavia. Metamorphism alone, he always contended, could not explain this essential difference. The conditions of life, he added, had been one thing in the seas that occupied the Siberian area, and another in the waters which covered the low countries of western and southern Europe during the Silurian epoch.

"Since that time, this distinction of the varying faunas in contemporaneously formed basins, separated from each other during the older paleozoic period, has been abundantly developed by M. Barrande, who has well shown the specific distinctions between the animals which inhabited respectively the regions of Bohemia and Scandinavia during the Silurian era. It is to the similarity, on the contrary, of the organic remains in the *northern zone of Silurian rocks*, which extends over so vast a space, that attention has been mainly directed on this occasion.

"Finally, let me state, that another chief object I have had, in bringing together the observations of Count Keyserling, Professor Schmidt, and M. Kjerulf, with comparisons of my own, is to demonstrate that in Scandinavia, as in Russia in Europe, Silurian rocks, both Lower and Upper, and copiously charged with characteristic organic remains, form a united and unbroken whole; and that, whether viewed paleontologically or geologically, they exhibit throughout those northern European regions, and in a very small compass, a natural-history system quite as complete, and more easily understood, than their much more expanded, highly varied, and dislocated equivalents in the British Isles."

In a broad classification of primeval life, one late eminent naturalist* considered that the Silurian rocks constitute the Lower Paleozoic,—the Devonian, Carboniferous, and Permian rocks the Upper Paleozoic. But, whether this ancient series be divided into double or triple classes, some paleontologists preferring to hold the Devonian as a separate and intermediate type,—the Lower and Upper Silurian rocks constituting truly an older natural system,

* Edward Forbes.

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just as the Carboniferous and Permian deposits form a younger one, —the result of the researches of the numerous authors appealed to in this volume has unquestionably justified the application of the term "system" to the Silurian rocks.

At the close of the Permian or supra-Carboniferous era, an infinitely greater change took place in organic life than that which marked the ascent from the Silurian system to the overlying paleozoic groups. All the species of the earlier races then disappeared, and were replaced in the Trias by an entirely new series, the types of which were continued through those long epochs which geologists term secondary or mesozoic (the medieval age of extinct beings). In these, again, the reader will learn, by consulting the works of many writers, how one formation followed another, each characterized by different creatures; many of them, however, exhibiting near their downward and upward limits certain fossils which link one reign of life on to another.

Whilst it is beside my present aim to enter upon descriptions of such Secondary deposits, still less of those called Tertiary, which intervened between the Secondary rocks and the sediments of the present day, we may still cast a glance over the general order admitted by geologists, to see how it harmonizes with what has been related of the succession of animals belonging to the older rocks, as indicating a progression from lower to higher grades of life.

Let me then again remind the reader, that he has been presented in this volume with clear proofs that an immensely long period elapsed, during which, with countless remains of all other inhabitants of the sea, no trace of a fish has been discovered, to represent the prototype of that vertebrate succession which terminated in Man. Next, he will have noted, that after fishes first appeared, long ages elapsed—those, in fact, which count from the Upper Silurian to the Middle Devonian, inclusive—before a reptile was added to the inhabitants of that epoch; and then, we have seen, that, notwithstanding the demonstration of the frequent submergences of enormous breadths of land, which were clothed with a rich and copious vegetation on which insects fed, no sign whatever has been met with, in the spoils of these well-explored Carboniferous and Permian domains, that they were inhabited by a single mammal!

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Proceeding upwards into the Secondary strata, the earliest traces of mammalia are first detected in the upper part of the Trias, or the Keuper Sandstone of Wirtemberg, which covers the Muschelkalk, and lies at the base of the Lias. In that deposit the relics of a solitary, small marsupial mammal have been exhumed, which its discoverer, Plieninger, has named Microlestes antiquus. Again, Dr. Ebenezer Emmons, the well-known geologist, of Albany, in the United States, has described, from the lower beds of the Chatham Secondary Coal-field, North Carolina (of the same age as those of Virginia, and probably of the Wirtemberg Keuper*), the jaws of another minute mammal, which he calls Dromotherium sylvestre. Lastly, while I write, Mr. C. Moore has detected, in an agglomerate which fills the fissures of the Carboniferous limestone, near Frome, Somersetshire, the teeth of marsupial mammals, one of which he considers to be closely related to the Microlestes antiquus of Germany, and Professor Owen confirms the fact. From that coincidence, and also from the association with other animal remains—the Placodus (a reptile of the Muschelkalk), and certain mollusca, Mr. Moore believes that these patches represent the Keuper of Germany. If this view should be sustained, this author, who has already made remarkable additions to our acquaintance with the organic remains of the Oolitic rocks and the Lias, will have had the merit of having discovered the first traces of mammalia in any British stratum below the Stonesfield Slate.

Ascending, then, from the Keuper or summit of the Trias, we have to traverse the whole of the Lias and the Lower Oolites or Jurassic formations, which are charged, at intervals, with many terrestrial vegetable remains and highly organized Saurians and Batrachians, generically unlike the lizards which preceded them, before we find another trace of mammalian life. Insects, which, as has been shown, first appeared in the era of the earliest great forests (Carboniferous), became more abundant in these Secondary rocks, and with these are found the bones of that oldest known large-winged (insectivorous?)

* I cannot admit, with my esteemed contemporary, Dr. Ebenezer Emmons, that the beds in which the small mammal he describes were entombed, can be referred to the Permian group, or close of the Paleozoic era. The absence of Permian molluscs, now known in other parts of North America (see p. 470), invalidates his view; and I have yet to learn that Sir C. Lyell or any American geologist would consider the beds in question to be older than the Keuper of Germany.

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reptile, the Pterodactyle. Still, surrounded as we are in these strata by plants, insects, and many reptiles, we have to journey through several of these Secondary deposits before we obtain any other evidence of the existence of mammalia than the jaws of another small marsupial, the Didelphys Bucklandi (Broderip) of the Stonesfield Oolite*, and its (possibly placental) little companion, the Phascolotherium of Owen.

Passing upwards through the superior Oolitic deposits, and rising considerably in the scale of formations,—when, in short, we are about to take leave of the Oolitic or Jurassic group (after forty years of examination), and are entering into the mass of the great estuarine formation, the Wealden, and approaching the base of the Cretaceous rocks, then it is, as might have been anticipated, that geologists have recently discovered proofs of the existence of many more mammalia than have been detected in any of the lower Secondary deposits. Through researches which began under the direction of Edward Forbes, and which in the last two years have unfolded great fossil wealth to the able and persevering labours of Mr. Beckles, a perfect mine of highly organized small mammalia has been opened out. Though it is not in my power to enter into details illustrative of the characters of these curious little animals†, which will shortly be thoroughly described by our great authority, Owen, I may refer the reader to a lucid memoir by Dr. Falconer, in which, besides a description of his Plagiaulax Becklesii and P. minor, referred by him to herbivorous or frugivorous species of marsupials, such as the Hypsiprymnus Gaimardi‡, he announces that the three Purbeck genera known up to that time were the Spalacotherium and Triconodon, Owen, and the Plagiaulax, Falconer. He further believes in the existence of "at least seven or eight genera of mammalia, some of them unquestionably Marsupialia, both predaceous and herbivorous, and others of them," he

* It was in the year 1827 that the Didelphys Bucklandi was described by that sound naturalist, my friend Mr. W. Broderip (Zoological Journal, vol. iii. p. 408).

† One of these little creatures is stated by Dr. Falconer to be of about the size of the Pigmy Flying Opossum. I am further informed by Dr. Falconer, that he found among the Purbeck fossils, collected by Mr. Beckles, abundant remains of a *Thecodont* Saurian, to which he has applied the designation of Saurechumodon, an account of which, by him, will appear hereafter. We thus learn that the mere presence of a Thecodont Saurian is no proof of the age of a deposit, since remains of this family of reptiles range from the Permian to the termination of the Oolitic series.

‡ Quart. Journ. Geol. Soc. 1857, p. 261.

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says, "conveying to my mind the impression, so far as the evidence goes, that they belong to the Placental Insectivora, having affinities more or less remote to existing types*."

Willingly granting to my eminent friend Sir C. Lyell all due credit for having anticipated the speedy advent† of the mammals which have since been disinterred by Mr. Beckles, I must be permitted to say, that, in my opinion, this discovery does not in any way invalidate the general inference of an advance in creation, as based upon the broad data here reiterated as in my former works, and derived from observation in many parts of the world.

Let me entreat the reader not to be led, by the reasoning of the ablest physiologist, or by an appeal to minute structural affinities, to impugn the clear and broad facts of a succession from lower to higher grades of life in each formation. Let no one imagine that, because the bony characters in the jaw and teeth of the Plagiaulax of the Purbeck strata are "such as the comparative anatomist might have expected to find among existing marsupials," and that the animal is therefore far removed from its embryonic archetype, such an argument disturbs the order of succession of *classes* as seen in the crust of the earth.

Leaving the true physiological doctrine to be worked out by others, I repeat, that the Purbeck discoveries are in accordance with the views of those geologists who cannot avoid recognizing distinct proofs, on the great scale, of a series of acts of creative power in the successive appearance of each great class of animals. The reader must therefore recollect, that, whilst the most laborious endeavours during the last quarter of a century have failed in detecting the trace of a mammal in the earlier formations treated of in this volume, the Purbeck strata, in which the remains of minute creatures of that class are first found in abundance, are *as modern* in the eyes of a paleozoic inquirer, as they are venerable in the estimation of the geologist whose studies of the earth's crust have been mainly directed to those Tertiary rocks in which, for the first time, in mounting from older to newer strata, we meet with a great variety and profusion of mammals, of all sorts and sizes, many of which are still the associates of Man. In such Tertiary formations, we have, indeed, before us on all sides the bones of the higher orders

* *Loc. cit.* p. 262. † See 'Manual of Elementary Geology,' 3rd edit. p. 236.

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of mammalia as drifted from numerous adjacent lands, associated with the exuviæ of marine creatures, which, though scarcely more abundant than those of the earlier formations, are all of different species.

Animals, in short, of every class, whether terrestrial or marine, and particularly mammalia, abound more and more in each succeeding formation of Tertiary age, exhibiting an increasing quantity and variety of both sea and land creatures as we approach the superficial accumulations. In these only are entombed the bones of gigantic quadrupeds,—quadrupeds which once inhabited our present continents, and which must have required for their sustenance a range over lands probably as extensive as those occupied by Man and his associates.

Let the reader dwell on these remarkable facts which the labours of geologists have elicited in the last fifty years. Let him view them in the clear and broad order indicated by Nature from an invertebrate to a vertebrate era, and next mark a regular rise thenceforward in the numbers and organization of animals by the addition, in successive epochs, first of reptiles and then of mammalia. Let him execute a patient survey from the lower deposits upwards, and, after passing through the largest portion of the long Silurian epoch without detecting a fish, he will find everywhere a succession of creatures rising from lower to higher organizations,—a doctrine first promulgated by the illustrious Cuvier, but from much less perfect data than we now possess*.

Yet, however they admit the facts, some of my contemporaries think that they can so explain them as to reject a belief in successive creations from lower to higher *classes*. They suppose, that nearly all the strata of date antecedent to those in which the first signs of life have been detected are often in so crystalline a state, that, if they originally contained remains of animals, the traces of them must have been obliterated by changes since effected in the structure of the rock. Now, if this supposition had been supported by the researches of late years, we must doubtless have admitted that the attempt to point to the earliest visible signs of creation is buried

* The paleozoic or primeval fossils were necessarily little known to that great comparative anatomist, who drew his conclusions from data within the scope of the knowledge of his day, *i. e.* from the higher orders of Vertebrata which appear in the more recent epochs only, and specially those of the Paris basin.

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in a hopeless obscurity; but this difficulty (which I would not underrate, being well aware that, covered up as they are in mountain masses and beneath great plains, the fauna and flora of every former period can never probably be perfectly known) is to a great extent set aside by the fact of the existence of deposits many thousands of feet thick, and scarcely at all altered, which, made up of sand, mud, and pebbles, constitute the very foundations of the fossil-bearing Silurian strata. In these huge lower sediments, one doubtful genus of Zoophyte with traces of Annelides or worms have alone been found, together with a portion of one obscure Trilobite (p. 26); whilst chemical analysis has afforded to Daubeny independent proofs that phosphoric acid, a true indicator of former life, is hardly to be detected in these older rocks, though it abounds in the younger and fossiliferous strata. (See Appendix P.) If this argument were derived from the evidences collected in one region only, it might have been suggested, that, as the same formation which is barren in life over one district teems with signs of it in another, so the Cambrian rocks may still prove to be more fossiliferous; but such infra-Silurian rocks have been well explored in many countries, and have not there afforded even the scanty signs of life which have been wrung from them in Britain.

When we proceed upwards into those Lower Silurian strata so replete with clear and well-defined groups of all marine animals except vertebrata, an antagonist might possibly reply, that gelatinous fishes, void of backbones (like the solitary little Amphioxus now living), *may* have been the only creatures of their class which swarmed in the broad seas then prevailing; and if so, that no traces of them could exist, their boneless bodies perishing and leaving no sign of their former existence. As an old student of Nature's works, I cannot allow this hypothesis to outweigh the very numerous and well-recorded facts which announce the co-existence and perfection of all the other classes of the ancient submarine kingdom. If thousands of invertebrate animals have left their coverings behind, and the most delicate impressions of their parts, is it rational to suppose that every form of fishes should be wanting in that framework which, whether consisting of dermal plates or of vertebræ, characterizes them in the strata of all succeeding epochs? Nay more, we see that in this same long period in which no traces of

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fishes appear there specially prevailed a superabundance of cephalopods; and, as creatures of that structure are well known to be carnivorous, we may presume that they were the appointed tyrants and chief scavengers of the Silurian seas.

Another hypothesis which has been advanced in opposition to the mass of positive evidence is, that, although such earlier rocks are void of ichthyolites, the sediments *may* all have been formed in limited zones around the earth; just as it is believed by some naturalists that there are seas subject to certain currents and conditions of the bottom in which no fishes are now living. But here, again, the application of such a theory, I would suggest, is still more negatived by the facts adduced. Silurian rocks similar in structure, and containing the same organic remains, are not confined to any one segment of the earth's surface, however broad, but are largely developed in nearly all known regions. The argument is, therefore, untenable in face of the knowledge we have acquired, that, amidst a profusion of all the other forms of marine life, fishes only are absent from strata formed in the seas of this early age.

The prevalence of a widely spread primeval ocean, and of a surface which had not yet been subjected to those innumerable variations of outline which have since changed and modified the different climates of the earth, when connected with a belief in the former greater radiation of heat from its interior, are the chief data required to satisfy us, that physical conditions then prevailed, with which the nature and extensive spread of the earlier groups of animals are in harmony.

Admitting that in the remote periods during which the earliest accessible sediments were accumulated, large areas of land (though probably of no very great altitude), as well as vast rivers, must have existed as sources of the primeval deposits, we may still well believe that such lands were widely separated by seas, and that hence we ought necessarily to meet with a smaller number of shore animals and a greater number of oceanic forms. Taking advantage of this simple fact, some persons have suggested that we may have as yet discovered only the deep-sea products of the Silurian period, and that, when the true edges of its lands come to be detected, we may then find plants and many creatures now unknown to us. To this I confidently reply, that many proofs have already been

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adduced of lands which were contiguous to the marine Silurians, both Lower and Upper. Innumerable pebble-beds, coral-reefs, and trails of animals that crawled upon the tide-marked mud, are the principal evidences required, and to these I will again presently advert.

It has also been said, that the great number of floating shells or cephalopods, particularly the Orthoceratites, which abounded in the Silurian era, are in themselves indicators of deep seas, remote from land, into which, therefore, terrestrial spoils were little likely to be transported. Now, the Silurian chambered shells may, indeed, have required a certain depth of water, and yet many of them, like the Nautilus Pompilius of the present day, might have lived at no great distance from the land of that time; for, in the succeeding Carboniferous period, when the mountain limestone was formed, we find no lack of floating shells and other mollusca equally characteristic of certain depths of water, and yet these are associated with abundance of plants which were drifted from land,—simply, as I would say, because the earth then bore a rich arboreal or tree vegetation; whereas we can discover only the feeblest traces even of vegetable tissue in the earlier Silurian time, notwithstanding the certain existence of contiguous lands and of large streams at that period. In all the subsequent formations of the geological series, from the Permian upwards, land-plants ever accompany marine remains. Thus, in the Lias and Oolites, for example, we meet with an equal, if not a greater number of floating shells than in the Silurian rocks. The Ammonites and Belemnites of the younger period, requiring the same depth of water, had taken the place of the primeval Orthoceratites; and yet, associated with them, we have everywhere proofs of the proximity of the land, in the abundance of fossil plants and wood derived from *terra firma*, doubtless then much more extensive and diversified than in the earliest times.

If the old continents and islands which existed during the accumulation of the marine Lower Silurian deposits had borne trees, the numerous researches of geologists in all quarters of the globe must have brought to light some signs of them*; for, whilst we know

* A year ago it was triumphantly announced, by those who are opposed to my matter-of-fact reasoning, that trees of considerable size had at length been discovered in the Silurian rocks of Anticosti; but on examination, the specimens were entirely discarded from the vegetable kingdom by Dr. Hooker (see p. 460).

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that there are rocks of considerable extent, which, from the fine nature of their materials, may probably have been deposited in an ocean at some distance from a shore (though we have as yet little or no evidence as to the accumulation of sediment in deep seas, where no currents prevail),—there are, on the other hand, many Silurian districts of the Old and New World, where the form and structure of the deposits bespeak the action of waves and surge, and where the imbedded sea-weeds, zoophytes, and other remains compel us to adopt the same view. If, also, the primeval fauna does afford fewer spiral univalve shells than are seen among the animals of the Laminarian zones of our modern seas, we may suggest that shore-lines, as we understand them, must have been much less numerous in primeval epochs than at the present day, now that the surface has been diversified by lofty dividing ridges on the land and corresponding depressions in the ocean. With this important reservation, we do, however, obtain as many of those signs of shores as we can expect to find in the earlier deposits.

Appeal, for example, to the oldest sedimentary deposits in which traces of any living thing have been detected, the Longmynd rocks of Britain, and see, in their mode of aggregation, in the sand-worms which burrowed into them, and in the rain-drops which dibbled their surface, the clearest proofs of shore-accumulation (pp. 26, 27).

Again, look to the illustrations of this point furnished by the American geologists, from a very wide extent of their country, where the strata are nearly horizontal, and where, without any ambiguity, our kinsmen have traced life downwards in the successive crusts of the earth, to the same primordial zone as their contemporaries have done in Britain*, Scandinavia, and Bohemia. The American geologists have evidences, in their lowest Silurian beds, of numerous trails or tracks of animals, whether crustaceans or gasteropods, which moved over a film of mud or sand formed by one tide before another covered the impressions, and left them as proofs to future ages, of layers which were deposited on the shores and edges of former lands. Again, in other Silurian beds of the far West, there exists the same abundance of coral-reefs as in Britain, and the still

* Mr. Salter has described a trail of the Hymenocaris vermicauda, in the Lingula flags of North Wales (Lowest Silurian of the Geological Survey): see Quarterly Journal of the Geological Society (May 1854), vol. x. p. 208. Other tracks are common in these beds.

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stronger evidence of pebbly and sandy shores, which never contain the trace of a land-plant. Why, therefore, wander from such plain facts into the region of theory? And why not admit (what is, indeed, in accordance with all we have observed) that nearly all the Silurian era had passed away before trees grew upon the land or fishes swam in the waters?

In the fundamental facts described in this volume, we cannot, therefore, but recognize arrangements which, though perfect as respected all truly primeval creatures and plants, were essentially different from those of our own time; for, if the then existing continents or islands had borne trees, some fragments of them must have been transported into adjacent estuaries, and mixed in the mud and sand, like the vegetables of every subsequent epoch, by the agency of those great streams of the mechanical power of which we have such decisive proofs. The Silurian rocks extend over areas as large as, if not larger than any great system of the following periods; and yet in them alone, I repeat, is there an entire absence of an arborescent vegetation derived from the then adjacent lands.

And here it is well to remind the student of the wide, if not universal, spread of the primeval strata. In the annexed small general Map of the World are represented all the regions over which one or more of the primeval fossil groups are known to exist, including those crystalline and igneous rocks which were formed before, or are associated with them*. In viewing the dark tint of this map we may suppose, that when such extensive paleozoic sea-bottoms were raised into lands, the former continents, from which the sediments had been derived, were submerged; but be this as it may, it is a fact, that in all quarters of the globe, Silurian strata constantly lie in juxtaposition to the other overlying paleozoic formations, and hence it is impossible to apply to the lowest strata any reasoning which does not also refer to those which repose upon them. For as the Silurian rocks are constantly found in the same longitudes and latitudes as the Devonian and Carboniferous, why is it that in the one there are never found traces of vertebrata and land-plants,

* The reader must not be critical as to the exact demarcation assigned to the paleozoic and crystalline rocks by the dark tint of this map, which marks the relative proportions of the primeval to the secondary and tertiary rocks. The chief intention is to direct the eye to all the regions where the older rocks prevail.

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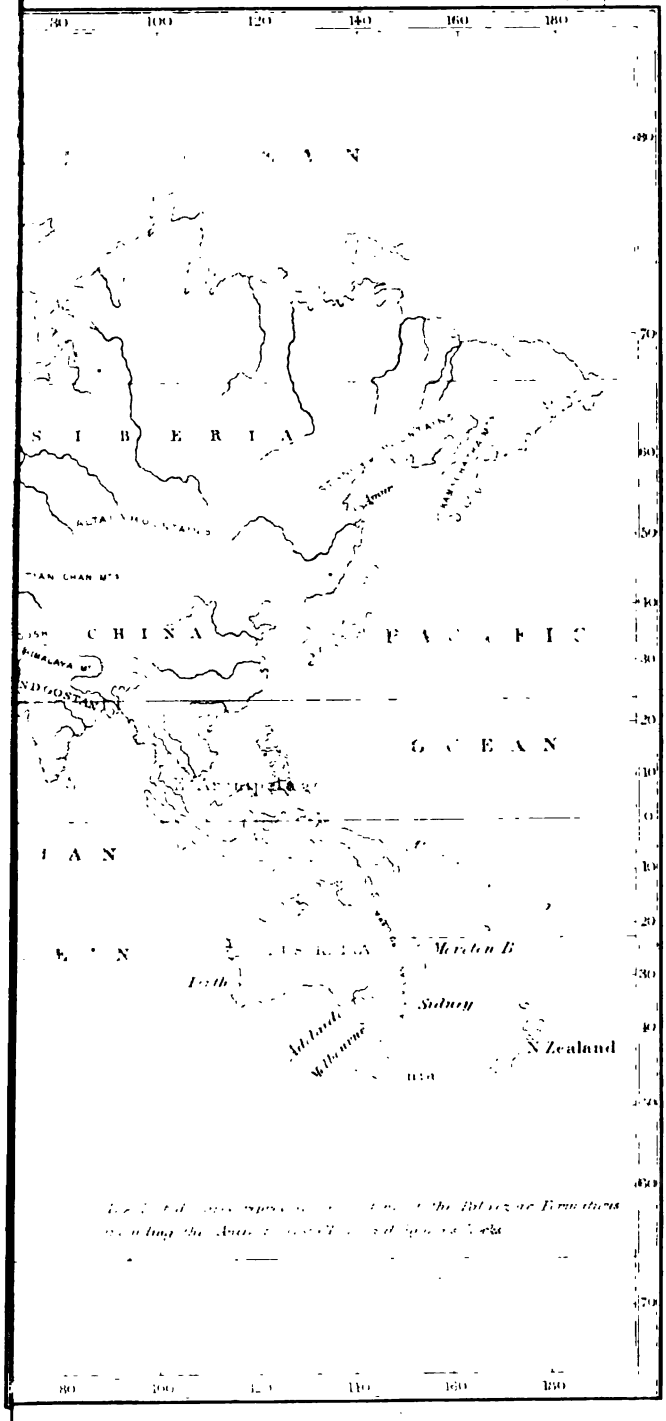

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and that in the very same region remains of both these classes abound in the other? By no theoretical suggestion, therefore, can the fair inference be evaded, that things which did not exist during the Silurian period were created in the same tracts or zones during the following ages.

The uniformitarian, who would explain every natural event in the earliest periods by reference to the existing conditions of being, is thus stopped at the very foundation-stone of the great edifice, each storey of which has been inhabited by different creatures. Nature herself, in short, speaks to him through her most ancient monuments, and tells him, that, though she has worked during all ages on the same general principles of destruction and renovation of the surface, there was formerly a distribution of land, in reference to the sea, very different in outline from that which now prevails. Such primeval state was followed by outbursts of great volumes of igneous matter from the interior, the extraordinary violence of which is made manifest by clear evidences. Fractures in the crust of the earth, accompanied by oscillations that suddenly displaced masses to thousands of feet above or beneath their previous levels, were necessarily productive of such translations of water, as to abrade and destroy solid materials, and spread them out over continents, to an extent infinitely surpassing any change of which the historical era affords an example.

I could here cite the works of Leopold von Buch, Elie de Beaumont, Studer*, Sedgwick, Buckland, Conybeare, De la Beche, W. Hopkins, and numerous other geologists, for countless proofs of this grander intensity of causation in former epochs, *i. e.* during many geological periods, by which gigantic masses were inverted, and strata forming mountains so wrenched, broken, and twisted as to pass under the very rocks out of whose materials they were constructed. The traveller amid the Alps and many other mountain-chains will there see signs of such former catastrophes, each of which resulted from convulsions utterly immeasurable by any reference to those puny oscillations of the earth which can be appealed to during the times of history. But restraining my pen on these collateral points, I adhere to our immediate subject—the proofs of a

* See particularly Studer's work, 'Geologie der Schweiz,' vol. ii. 1853.

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series of acts of creation coincident with former conditions, apart from such great physical revolutions.

If we reflect upon the succession presented to us in the primeval rocks, we have, I repeat, cumulative evidence, that the widespread diffusion of the same types of animal and vegetable life was due to a former temperature and outline of the surface essentially distinguished from those of our day. To whatever extent continents and islands may have existed during those long early periods, and however we may speculate on the extent of pristine shores, it seems certain, that the lands accessible to our survey and bearing any such vegetation increased very considerably in the carboniferous times. In those days the very same species of marine animals lived from the latitude of Spitzbergen to the parallels of Peru and Australia*. Vast, low deltas then also extended themselves, which, on being desiccated, bore an absolutely uniform terrestrial vegetation over at least half the globe. Many of the ancient tree-ferns must have grown on tracts little above the water, and jungles larger than Britain must have been successively and repeatedly submerged and re-elevated to form new lands, to be in due time covered by the vegetation that supplied the elements for the construction of great coal-fields. These phenomena assure us, therefore, that a very great portion, if not the whole surface of the earth, enjoyed at that time an equable and warmer climate. (See Sketch, p. 305.)

Believing, as I do, with many geologists, that this former temperature of the earth was, in great measure, caused by the radiation of its internal heat, independently of solar action, other physical as well as zoological phenomena lead me further to suppose, that the land of those early days could not have been thrown up into very lofty mountains; for, if so, such great elevations must have been accompanied by corresponding deep chasms in the crust of the earth, and these would necessarily have been impassable barriers †

* See the observations of d'Orbigny, p. 455. The Peruvian Andes, and other parts of the Cordillera ranging into California, have afforded several species of carboniferous mollusca identical with British forms, and I have myself found the same in the Ural Mountains. See 'Russia in Europe and the Ural Mountains,' vol. i. p. 73. They also occur in Australia: see M'Coy, Ann. Nat. Hist. 1847.

† Cuvier and Valenciennes showed (Hist. Poiss.) that very few species of fish cross the Atlantic; and the Reports to the British Association by Sir J. Richardson (1836, 1845) lead us to infer, that deep seas are as impassable barriers to fishes as high mountains are to mammals.

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to many of the primeval submarine creatures which have been described as co-existent over the most remote regions. Profound abysses of the ocean are, it is well known, as complete barriers to the migration of fishes and many other marine creatures, as lofty mountains are to inhabitants of the land. The recent discovery, therefore, of the vast profundity of the ocean midway between the Cape of Good Hope and Cape Horn, amounting to 7000 fathoms, or nearly double the height of the loftiest mountains (even allowing for some amount of error in the soundings), is, indeed, the strongest possible illustration of the impassable nature of such subaqueous barriers. These have resulted from oscillations of the surface, which, occurring during all geological time, have necessarily caused great variations in the marine provinces of life, placing them in strong contrast with the uniformity of the ancient faunas.

Duly estimating the great value of the knowledge of submarine life acquired and applied by a naturalist, whose researches, coupled with those of Lovén and other contemporaries, have thrown new light on many phenomena previously unexplained, let us guard against the inference, that, because such acquaintance with the natural operations of our own era is applicable to the last geological data, or those of tertiary age, it should also apply to the *quasi* universal, and therefore very different, physical conditions under which primeval creatures existed. During the tertiary period, the crust of the earth had, as we know, approximated considerably to its present varied outline, and, before it drew to a close, great changes had taken place, by which regions formerly occupied by animals and plants requiring a warm and equable climate were covered even by ice and glaciers. Whilst, therefore, we thank Edward Forbes for dredging the sea-bottoms, and teaching us that deep-sea mollusks are now living near high lands in the Mediterranean, whence pebbles may be so washed down as to lie in juxtaposition with the tenants of the deep,—we must believe that, either this argument cannot bear upon the primeval era, in which we have no evidence whatever of high lands and detached mediterranean seas,—or, if applied, it is the strongest evidence to show, that the supposed primeval cliffs and lands were void of terrestrial vegetation.

On what data, it may be asked, is founded the beautiful and rational theory of Lyell, which explains the successive changes of the

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climate of the earth? Is it not mainly dependent on those diversified evolutions, proceeding from beneath the surface, which have caused changes in the outline of former lands and seas, equivalent in extent, although different in position, to our present continents and oceans? And, if such a varied distribution of earth and water as the present had existed in the pristine periods that we have been considering, how could the same groups of animals, manifestly requiring the same conditions, the same temperature, and the same food, have had so wide a diffusion?

Although it is quite true that specific distinctions are seen to have frequently prevailed in the fossils of the Lower Silurian rocks of countries situated at no great distance from each other, as explained in the chapters which treat of the distribution of the fauna of that age, the fact is by no means antagonistic to my reasoning. Should it, for example, be even said, that the variety in the distribution of Silurian species is as great as in the same areas of sea of the present day, I reply, that it is not to species, but to the classes, groups, and genera, that the objector must appeal. If unable to explain why, in the earliest primeval times, so many Trilobites, Orthides, Orthoceratites, and Corals of analogous forms were spread out over areas at enormous distances, it is enough for us to feel assured, that the various associates of the Calymene Blumenbachii, or any other well-known Trilobite, must have required just the same temperature and surrounding media in whatever part of the world they lived. It is not because the land animals of Europe are dissimilar in *species* to those of Africa that the faunas of the two regions are so distinct, but that we have not among our European associates the same *groups* as those which live in hotter climes. I therefore conceive, that the fact of the diffusion of the same families and genera of Trilobites, Corals, and other fossils, however they may vary as to species, must have required an equably diffused temperature and similar conditions for their existence. Still more clearly is this inference sustained by the spread of the same old vegetation, and often of the same species of plants, over half the globe.

Resting then on these universal facts as a firm basis, the geologist who explores his way upwards, sees, as before stated, that the formations which were next accumulated in the same latitudes and longitudes as the Silurian rocks were, and sometimes in actual and

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conformable contact with them, do contain land-plants mixed with marine remains. In short, the only prevailing unequivocal vegetables found in the older strata are sea-weeds; whilst the later-formed and contiguous rocks, though equally charged with exuviæ of the sea, are laden with many spoils of the land, both vegetable and animal.

Patient researches having thus demonstrated, that in the primeval eras all living things differed completely from those of our own times, we also see how the animals subsequently created were adapted to new and altered physical conditions. Proceeding onwards from the early period in which we can trace no sign of trees or of vertebrata, and in which the solid materials, enclosing everywhere a similar fauna, were spread out with great uniformity, we soon begin to perceive the proofs of powerful revolutions, chiefly commencing after the coal formation*, by which the earth's surface was so corrugated, that, after many perturbations, the groups of animals and plants of the younger tertiary periods were infinitely more restricted than before to limited regions and climates. And, as the highly diversified conditions of the latest geological era and of the present day were wholly unknown in the primeval epochs, so it follows, that we should greatly err, if we endeavoured to assimilate the intensity of causation of all ancient nature with existing operations.

The numerous and positive evidences of a former wide distribution of similar animals and plants enable us fairly to bring before our mind's eye the physical geography of those great epochs when such large portions of our present continents were under the waters, and jungles of succulent and fern-like trees occupied extensive low lands, subjected during long periods to sinkings and uprisings Not less clearly do we perceive, from other physical evidences, the manner in which eruptive forces subsequently breaking out with great violence after the close of the carboniferous era, and, indeed, at many other

* I by no means deny that much perturbation prevailed in the earlier stages of the planet, as explained in the first two chapters. On the contrary, I admit the powerful emission of much igneous matter, the transmutation of sedimentary into crystalline rocks, and the presence of great terrestrial masses, anterior to the accumulation of any of the deposits which are now under consideration. But I deny that there are indications of the existence of any very lofty mountains, until the crust of the earth had undergone some of the subsequent mutations alluded to; particularly those which followed the accumulation of the carboniferous strata, and which were repeated at so many subsequent periods, notably, and perhaps most powerfully, in the tertiary times which preceded the historic era.

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periods, and powerfully in very recent geological times, have thrown the strata into those grand undulations and contortions, accompanied by stupendous fractures, which have given to the older and younger paleozoic deposits their curvatures and limits.

Thenceforward was continued that long series of additional and repeated emissions of volcanic matter from within, of elevations of the sea-bottom, and corresponding depressions of land, combined with the metamorphism of strata (these changes being often accompanied by corresponding new creations of animals suited to the existing conditions), during the formation of the secondary and tertiary deposits. By these great physical operations, both gradual and paroxysmal, our planet was eventually brought to possess the climatal relations which have for so long a time prevailed. That these elevations and depressions finally produced a state of things very different from that of such former eras, is everywhere registered by a multitude of well-attested data.

Among the terrestrial changes to which science clearly points, there is no one which better deserves to be recorded in a few parting words, than that great mutation of surface and its accompanying loss of warmth, by which extensive fields of ice were, as I believe, first formed upon the sea, and large glaciers upon the land. As very lofty mountains in moderate latitudes, and masses of land and water in Arctic or Antarctic regions, are essentially the seats of glaciers and ice-rafts—so we know that these bodies alone have the power of transporting huge erratic fragments of rocks from their native mountains to considerable distances by land, or for hundreds of miles over the sea in floating icebergs. Now, of the far removal of such gigantic blocks we have no clear evidence in any preceding geological period! On the contrary, whilst most large boulders of the primary, secondary, or older tertiary rocks bear on their surfaces the signs of having been waterworn or rounded by aqueous or atmospheric agency, the huge erratics of the later cold period (gigantic in comparison with all that preceded them) are often angular, or nearly in that state in which they left the mountain-side,—before, in short, they were wafted over seas or lakes, to be dropped, at very remote distances from their parent rocks, upon submarine sediments which by subsequent elevation have been made portions of our continents. Hence, independently of the indications of a

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more equably diffused and warmer temperature in older times than at the present day, such large erratics are in themselves decisive testimonials of that intense cold, which, it is believed, was principally due to the increase of great elevated masses of land which specially characterize the *quasi* modern period.

Receding backwards from this glacial phenomenon, which, continuing into our own times, has been so skilfully illustrated by eloquent writers*, it is specially my province to endeavour to impress upon the reader the importance of endeavouring to form an estimate of the physical geography of the earth during those remote periods when the Paleozoic deposits were accumulated. If very lofty mountains did not then exist, we have, indeed, in this single phenomenon, what may have been one of the chief causes of that equable, if not warmer climate, the presence of which, though a hypothesis, seems indispensably requisite to harmonize with the facts recorded in this volume. And if we add the inference adopted by many philosophers and geologists, that the earth, in cooling down from its original molten state, must, during long succeeding ages, have diminished in heat over its whole surface, we are enabled, by reference to physical changes alone, to satisfy ourselves that we have in them the chief elements required to explain all climatal results.

Finally, if this retrospective survey of the changes of the earth be but the outline of a picture which must be filled up by an assiduous study of the works of nature, let me say that it has not been attempted without deliberate consideration and extensive researches amid the youngest as well as the most ancient deposits. And, if any theoretical portions of the preceding pages be objected to, they can easily be separated from those historical facts which are established by positive observation, and in the truth of which all geologists are agreed.

The leading object of this volume is to call attention to the oldest vestiges of life which have been discovered in the crust of the globe, and accurately to chronicle the order in which other early races followed them.

From the effects produced upon my own mind through the long study of these imperishable records, I am, indeed, led to hope that most of my readers will adhere to the views which, in common with

* See Charpentier, Agassiz, and particularly the admirable writings of James Forbes.

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many contemporaries, I entertain of the succession of life from lower to higher classes; albeit the first created animal of each class may have been as perfect as any of its congeners in after-times. For, he who endeavours to look to a beginning, and who, commencing with the earliest visible signs of life, can thenceforward trace a successive rise in the scale of being, until that period is reached when Man appeared upon the earth, must acknowledge in such works repeated manifestations of the design and superintendence of a CREATOR.

FINIS.

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APPENDIX.

A.—*Table showing the Vertical range of the Silurian Fossils of Britain.*

In the Appendix to the former edition of this work, the range of those species only which are common to the great divisions Upper and Lower Silurian was exhibited in a tabular form. I am now enabled to give a complete list, so far as our present knowledge extends, of all the species, and to particularize their occurrence in the subdivisions of the system;—thus following the plan adopted in the original 'Silurian System.'

Mr. Salter, aided by Mr. Morris, has drawn up the following Table as a basis for the more complete Silurian catalogues on which he has been for some time engaged, and which will contain many more species, not yet described. In the preparation of this list he has found it necessary to modify the statements of some of my contemporaries, with regard to the species found in those portions of the series on which we have now better geological data—the Llandeilo and Llandovery groups for instance. If any published species are omitted, or combined with others, it is because a careful examination has convinced him of their identity with previously described forms. With these exceptions, the list combines the labours of all British writers on Silurian fossils, and shows at a glance the number which are common to two or more subdivisions.

The Lingula flags ("Zone primordiale" of the Silurian rocks of Barrande) are, according to my view, represented in Shropshire by the Stiper Stones, which immediately overlie the Cambrian rocks of the Longmynd. This zone has recently yielded fossils which connect it with the Llandeilo flags. (See Appendix R.) In Norway it contains two or three species common to it and the Llandeilo rocks.

The Llandeilo rocks are black, flag-like, and slaty deposits, occasionally calcareous, extensively developed in Shropshire and N. and S. Wales. They include at their base the dark grey flagstones and schists which occupy the western slopes of the Stiper Stones (see pp. 52 *et seq.*).

In the Caradoc or Bala column are included all the rocks of the Caradoc sections of Shropshire, the Bala limestone, and the arenaceous beds above and below it, which beds all overlie the black slaty Llandeilo series in N. and S. Wales (see pp. 48–66). The fossils of Snowdon, of Coniston in Westmoreland, of Ayrshire, Tyrone, Dublin, Waterford, Wexford, &c., are all included in the "Caradoc," a principal member of the Lower Silurian division.

In the column "Llandovery Rocks," both the upper and lower divisions are united, as they form one natural-history division; but the reader will see that in the text I have clearly indicated their distinction. The fossils from Galway in Ireland, separately treated of in my last list, are here included in the Llandovery rocks.

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The Woolhope limestone and Denbighshire grits are here regarded as the lowest portion of the Wenlock rocks, and Mr. Salter has included the Coniston grits of Prof. Sedgwick: these last contain but few species. The fossils of the Bogmine, Shelve, Shropshire, are also thus placed, as they are nearly all Upper Silurian species.

The Ludlow column embraces the Lower and Upper Ludlow rocks and the intervening Aymestry limestone; whilst the term "Passage-beds" refers to that thin band only, which exhibits a passage from the Upper Ludlow to the Old Red Sandstone—the Downton Castle stone being retained with the former (pp. 149, 156).

[In the following list, references are made to the Woodcuts of Fossils in the text, and to the Plates at the end of the work, in a distinct and darker type.]

	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
PLANTÆ.							
ACTINOPHYLLUM plicatum, Phil. M. G. S. ii. p. 386						*	
CHONDRITES regularis, Harkn. Geol. Journ. xi. p. 473		*					
? CRUZIANA semiplicata, Salt., **Foss. 4.** f. 3	*						
FUCOIDES, n. sp., **Foss. 15. p. 106**				*			
LYCOPODIACEÆ, **p. 267. Pl. 35.** f. 30						*	*
PALÆOCHORDA major, M'Coy, Pal. Fos. t. 1 A		*					
minor, M'Coy, Pal. Fos. t. 1 A		*					
teres, Harkn. Geol. Journ. xi. p. 474		*					
SPONGARIUM æquistriatum, M'Coy, Pal. Fos. p. 42						*	
Edwardsi, Murch., **Pl. 12.** f. 3						*	
interlineatum, M'Coy, Pal. Fos. p. 43						*	
interruptum, M'Coy, Pal. Fos. p. 43						*	
TRICHOIDES ambiguus, Harkn. Geol. Jour. xi. p. 474		*					
AMORPHOZOA.							
ACANTHOSPONGIA Siluriensis, M'Coy, Sil. Fos. p. 67			*				
CLIONA (Vioa) antiqua, Portl. Geol. Rep. p. 360			*				
prisca, M'Coy, Pal. Fos. t. 1 B. f. 1				*			
CNEMIDIUM tenue, Lons., **Pl. 38.** f. 11					*		
STROMATOPORA striatella, d'Orb. (S. concentrica, Sil. Syst.), **Foss. 51; Pl. 41.** f. 31			*	*	*		
? VERTICILLOPORA abnormis, Lons., **Pl. 38.** f. 10					*		
ZOOPHYTA.							
ACERVULARIA ananas, Linn., **Foss. 53.** f. 6; **Pl. 39.** f. 6. (Cyath. dianthus, f. 12 *a*.)					*		
ALVEOLITES Grayi, Edw. Brit. Cor. p. 262					*		
Labechei, Edw. (Favosites spongites, Lons.), **Foss. 17.** f. 5; **Pl. 40.** f. 8			*?	*	*		
repens, Linn. (Fav. oculata), **Foss. 17.** f. 6					*		
? seriatoporoides, Edw. Br. Cor. p. 263					*		
ARACHNOPHYLLUM typus, M'Coy, **Foss. 52.** f. 6 (? Strombodes Murchisoni, Phillipsi, diffluens, Labechei, M.-Edw. Acervularia Baltica, **Pl. 39.** f. 8.)				*	*		
AULACOPHYLLUM mitratum, His. Leth. Suec. p. 100					*		

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
AULOPORA serpens, &c. (see Syringopora, Bryozoa, &c.)							
CHÆTETES ? Fletcheri, Edw., **Pl. 40.** f. 9					*		
pulchellus, Edw. Brit. Cor. p. 267					*		
CLADOCORA sulcata, Lons. (see Cyathophyllum).							
CLISIOPHYLLUM vortex, M'Coy, Pal. Foss. p. 33					*		
CHONOPHYLLUM perfoliatum, Edw. Brit. Cor. p. 291					*		
CŒNITES intertextus, Eichw. (Limaria fruticosa, Lons.), **Pl. 38.** f. 8					*		
juniperinus, Eichw., **Foss. 19.** f. 3. (Limaria clathrata, **Pl. 38.** f. 7)					*		
labrosus, Edw. Brit. Cor. p. 277					*		
linearis, Edw. Brit. Cor. p. 277					*		
strigatus, M'Coy, Pal. Foss. p. 22					*		
CYATHAXONIA Siluriensis, M'Coy, Pal. Foss. p. 36						*	
CYATHOPHYLLUM angustum, Lons., **Pl. 39.** f. 9				*			
articulatum, Wahl. (cæspitosum, Lons. *non* Goldf.), **Foss. 53.** f. 1; **Pl. 39.** f. 10. (Cladocora sulcata, Sil. Syst. ?, **Pl. 38.** f. 9)					*		
flexuosum, Lons., **Pl. 39.** f. 7					*		
Loveni, Edw. Brit. Cor. p. 280					*		
truncatum, Linn., **Foss. 53.** f. 2 (C. dianthus, Lons., **Pl. 39.** f. 12, 12 *b*, *c*, *d*.)					*		
CYSTIPHYLLUM brevilamellatum, M'Coy, Pal. Foss. p. 32					*	*	
cylindricum, Lons., **Foss. 53.** f. 8; **Pl. 38.** f. 3					*		
Grayi, Edw. Brit. Cor. p. 297					*		
Siluriense, Lons., **Foss. 53.** f. 7; **Pl. 38.** f. 1					*		
DIPHYPHYLLUM flexuosum, d'Orb. Prod. p. 48					*		
FAVOSITES alveolaris, Blainv. (F. aspera, d'Orb.), **Foss. 17.** f. 4; **Pl. 40.** f. 1, 2			*	*	*	*	
cristata, Blum., **Foss. 17.** f. 1; **Pl. 41.** f. 2 (F. polymorpha, Sil. Syst.)				*	*	*	
Gothlandica, Linn., **Foss. 17.** f. 2, 3; **27.** f. 6; **Pl. 40.** f. 3, 4				*	*		
Hisingeri, Edw. Brit. Cor. p. 259					*		
multipora, Lons., **Pl. 40.** f. 5					*		
oculata, Goldf. (see Alveolites).							
FISTULIPORA decipiens, M'Coy, Pal. Foss. p. 11					*		
GONIOPHYLLUM Fletcheri, Edw. Brit. Cor. p. 290					*		
pyramidale, His. Leth. Suec. p. 101				*	*		
HALYSITES catenularius, Linn. (Catenipora escharoides), **Foss. 19.** f. 6; **28.** f. 4; **Pl. 40.** f. 14		*	*	*	*		
HELIOLITES favosus, M'Coy, Pal. Foss. p. 15			*				
Grayi, Edw. Arch. Mus. v. p. 217					*		
inordinatus, Lons., **Foss. 27.** f. 5; **Pl. 38.** f. 12. (Porites, Sil. Syst.)			*				
sp. (Porites inordinata, M'Coy, Sil. Foss. Irel. p. 62)					*		
interstinctus, Wahl. (Porites pyriformis, Sil. Syst.), **Foss. 18.** f. 3–5; **Pl. 39.** f. 2			*	*	*	*	

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
HELIOLITES megastoma, M'Coy, **Foss. 27.** f. 7	.....	.....	*	*	*		
petalliformis, Lons., **Foss. 18.** f. 2; **Pl. 39.** f. 4. (Porites, Sil. Syst.)	.....	.....	*	*	*		
subtilis, M'Coy, Pal. Foss. p. 17	.....	.....	.....	*			
tubulatus, Lons., **Foss. 18.** f. 1; **Pl. 39.** f. 3	.....	.....	*	*	*		
? discoideus (Porites), **Pl. 39.** f. 1	.....	.....	.....	.....	*		
LABECHIA conferta, Lons., **Pl. 39.** f. 5	.....	.....	.....	*	*		
LONSDALEIA Wenlockensis, M'Coy, Pal. Foss. p. 34	.....	.....	.....	.....	*		
NEBULIPORA Bowerbanki, Edw. Brit. Cor. p. 268	.....	.....	.....	.....	*		
explanata, M'Coy, Pal. Foss. p. 23	.....	.....	*				
favulosa, Phil., **Foss. 10.** f. 22	.....	*					
var. lens, M'Coy, **Foss. 12.** f. 13	.....	.....	*				
papillata, M'Coy, Pal. Foss. p. 24	.....	.....	*	.....	.....	*	
OMPHYMA Murchisoni, Edw., **Pl. 38.** f. 2	.....	.....	.....	.....	*		
turbinatum, Linn., **Foss. 53.** f. 4, 5. (Cyathophyllum, Lons., **Pl. 39.** f. 11)	.....	.....	*	*	*		
PALÆOCYCLUS Fletcheri, Edw. Arch. Mus. v. p. 205	.....	.....	.....	.....	*		
porpita, Linn., **Foss. 52.** f. 3, 4	.....	.....	.....	.....	*		
præacutus, Lons. (and lenticulatus, Lons. *non* Schlot.), **Pl. 41.** f. 4, 5	.....	.....	.....	*	*		
rugosus, Edw. Arch. Mus. v. p. 206	.....	.....	.....	.....	*		
PETRAIA æquisulcata, M'Coy, Pal. Foss. p. 39	.....	.....	*	*			
bina, Lons., **Foss. 52.** f. 7, 8; **Pl. 38.** f. 5	.....	.....	.....	*	*		
elongata, Phil., **Pl. 38.** f. 6	.....	.....	*?	*			
rugosa, Phil. P. F. p. 7	.....	.....	*	*			
subduplicata, M'Coy, **Foss. 14.** f. 11; **28.** f. 3	.....	.....	*	*			
unisorialis, M'Coy, Pal. Foss. p. 41	.....	.....	*	*			
ziczac, M'Coy, Pal. Foss. p. 60	.....	.....	.....	*			
PTYCHOPHYLLUM patellatum, Schl. (Strombodes plicatum, Lons.), **Foss. 52.** f. 5; **Pl. 38.** f. 4	.....	.....	.....	.....	*		
PYRITONEMA fasciculus, M'Coy, Pal. Foss. p. 10	.....	*					
SARCINULA organum, Linn., **Foss. 27.** f. 4	.....	.....	*	.....	*		
STENOPORA fibrosa, Goldf., **Foss. 17.** f. 7; **28.** f. 1, 2 (Favosites, **Pl. 40.** f. 6, 7)	.....	*	*	*	*	*	
var. incrustans, M'Coy, **Foss. 17.** f. 8; **Pl. 41.** f. 1. (Alveolites fibrosa, Lons.)	.....	.....	.....	.....	*	*	
var. Lycoperdon, Hall, **Foss. 28.** f. 2	.....	.....	*				
STREPHODES Craigensis, M'Coy, Pal. Foss. p. 30	.....	.....	*				
pseudoceratites, M'Coy, Pal. Foss. p. 30	.....	.....	.....	.....	*		
trochiformis, M'Coy, Pal. Foss. p. 31	.....	.....	.....	.....	*		
vermiculoides, M'Coy, **Foss. 53.** f. 3	.....	.....	.....	.....	*		
SYRINGOPORA bifurcata, Lons. (reticulata, Lons. *non* Goldf.), **Foss. 19.** f. 2, 4, 5; **Pl. 40.** f. 10, 11	.....	.....	.....	*	*	*	
? cæspitosa, Lons., **Pl. 40.** f. 13	.....	.....	.....	.....	*		
fascicularis, Linn. (filiformis, Lons. ?, Aulopora tubæformis, Lons.), **Pl. 40.** f. 12; **Pl. 41.** f. 8	.....	.....	.....	.....	*		
serpens, Linn. (Aulopora serpens, conglomerata, Lons. *non* Goldf.), **Pl. 41.** f. 6, 9	.....	.....	.....	.....	*		
Lonsdaleana, M'Coy, Sil. Foss. p. 65	.....	.....	*	.....	*		
THECIA Grayana, Edw. Brit. Cor. p. 279	.....	.....	.....	.....	*		
Swindernana, Goldf. (Porites expatiata, Sil. Syst.), **Foss. 52.** f. 1, 2; **Pl. 41.** f. 3.	.....	.....	.....	.....	*	*	
ZAPHRENTIS (Caninia) lata, M'Coy, Pal. Foss. p. 28	.....	.....	.....	.....	*		

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
ECHINODERMATA.							
Actinocrinus pulcher, Salt. App. Pal. Fos. p. i.					*		
Agelacrinus Buchianus, Forbes, **Foss. 30.** f. 6.			*				
Apiocystites pentremitoides, Forbes, **Foss. 54.** f. 4					*		
Caryocystites (**p. 207**), (see Echinosphærites and Sphæronites).							
Cheirocrinus ‡ serialis, Aust. MS.					*		
sp. with branched arms (coll. Fletcher)					*		
Cophinus dubius, König, **Pl. 12.** f. 5 (tracks of Crinoidea)						*	
Crotalocrinus rugosus, Mill. sp., **Pl. 13.** f. 3; **Foss. 55.** f. 4–7					*		
Cyathocrinus arthriticus, Phil., **Pl. 14.** f. 7					*		
capillaris, Phil., **Pl. 15.** f. 3 (Poteriocrinus radiatus, Austin)					*		
(Poteriocrinus) Dudleyensis, Austin, Ann. N. Hist. 1843, p. 195					*		
goniodactylus, Phil., **Pl. 14.** f. 3					*		
Dimerocrinus decadactylus, Phil., **Pl. 13.** f. 5					*		
icosidactylus, Phil., **Pl. 13.** f. 4					*		
Echino-encrinites armatus, Forbes, **Foss. 54.** f. 6					*		
baccatus, Forbes, **Foss. 54.** f. 5					*		
Echinosphærites arachnoideus, Forbes, M. G. S. ii. p. 518			*				
aurantium, Gyll. M. G. S. ii. p. 516			*				
Balticus, Eichw., **Foss. 30.** f. 1			*				
Davisii, M'Coy, sp., Pal. Fos. p. 61			*				
(Caryocystites) granatus, Wahl., **Foss. 30.** f. 5			*				
granulatus, M'Coy, **Foss. 30.** f. 3			*				
Enallocrinus punctatus, His. Leth. Suec.					*		
Eucalyptocrinus (Hypanthocrinus, Phil.) decorus, Phil., **Pl. 14.** f. 2					*		
granulatus, Lewis, Lond. G. J. t. 21					*		
polydactylus, M'Coy, Pal. Fos. p. 58					*		
Glyptocrinus? basalis, M'Coy, **Foss. 29. p. 206**			*				
expansus, Phil., **Pl. 15.** f. 1, 2					*		
(Trochocrinus) lævis, Portl. G. R. p. 345			*				
sp., **Pl. 10.** f. 1				*			
Glyptocystites (see Pleurocystites).							
Hemicosmites oblongus, Pand.?, M. G. S. ii. p. 511			*				
pyriformis, Buch, M. G. S. ii. p. 511			*				
squamosus, Forbes, M. G. S. p. 510			*				
Ichthyocrinus pyriformis, Phil. sp., **Pl. 14.** f. 8					*		
Ischadites Kœnigii, Murch., **Pl. 12.** f. 4						*	
Lepidaster Grayi, Forbes, Decade 3. t. 1					*		
Macrostylocrinus, (Hall) sp.						*	
Marsupiocrinus cælatus, Phil., **Pl. 14.** f. 1; **Foss. 55.** f. 1–3					*		
Palæaster asperrimus, Salt., **Foss. 31.** f. 2			*				
coronella, Salt. Ann. N. H. s. 2. xx. p. 326				*			
hirudo, Forbes, **Foss. 56.** f. 2						*	

‡ This and other MS. names are only introduced for important fossils, and can have no authority: the above is the Pendulocrinus of Austin, MS.

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
PALÆASTER obtusus, Forbes, sp., **Foss. 31.** f. 1			*				
Ruthveni, Forbes, **Foss. 56.** f. 3						*	
PALÆCHINUS? Phillipsiæ, Forbes, M. G. S. ii. p. 384				*			
PALÆOCOMA Colvini, Salt., **Foss. 20.** f. 4						*	
cygnipes, Salt. Ann. N. H. s. 2. xx. p. 329						*	
Marstoni, Salt., **Foss. 20.** f. 3						*	
(Bdellacoma) vermiformis, Salt. Ann. N. H. ser. 2. xx. p. 329						*	
PALMODISCUS ferox, Salt. A. N. H. s. 2. xx. p. 333						*	
PALASTERINA primæva, Forbes, **Foss. 56.** f. 1						*	
PERIECHOCRINUS, sp.				*			
articulosus, Aust. Ann. N. H. 1843, p. 204					*		
moniliformis, Mill., **Pl. 13.** f. 1, 2				*	*		
PISOCRINUS ? ornatus, Kon. Bull. A. R. Brux. iv. p. 93					*		
pilula, Kon. Bul. A. R. Brux. iv. p. 93					*		
PLATYCRINUS (Actinoc.) retiarius, Phil., **Pl. 14.** f. 9					*		
PLEUROCYSTITES (Glyptocyst.) Rugeri, Salt., **p. 229**				*			
POTERIOCRINUS (see Cyathocr. Dudleyensis, Aust. Ann. N. H. 1843, p. 195).							
PROTASTER leptosoma, Salt. A. N. H. s. 2. xx. p. 331						*	
Miltoni, Salt., **Foss. 20.** f. 1, 2						*	
Salteri, Sedgw. G. J. i. p. 20			*				
Sedgwicki, Forbes, **Foss. 56.** f. 4						*	
PRUNOCYSTITES Fletcheri, Forbes, **Foss. 54.** f. 3					*		
PSEUDOCRINITES bifasciatus, Pearce, M. G. S. ii. p. 496					*		
magnificus, Forbes, **Foss. 54.** f. 1					*		
oblongus, Forbes, Mem. G. S. ii. p. 499					*		
quadrifasciatus, Pearce, **Foss. 54.** f. 2					*		
RHODOCRINUS? quinquangularis, Mill. Crin. p. 109			*				
RHOPALOCOMA pyrotechnica, Salt. A. N. H. xx. p. 329						*	
SAGENOCRINUS (see Glyptocrinus).							
SPHÆRONITES Litchi, Forbes (Caryocyst. **p. 207**), M. G. S. ii. pt. 2. p. 514			*				
munitus, Forb. (Caryocyst.) **Foss. 30.** f. 4			*				
punctatus, Forbes (Echinosph. **p. 207**), **Foss. 30.** f. 2			*				
pyriformis, Forbes (Caryocyst.), M. G. S. ii. p. 515			*				
TAXOCRINUS (Cyathocr. **p. 246**) Orbignyi, M'Coy, Pal. Fos. p. 53						*	
tesseracontadactylus, His., **Pl. 14.** f. 4 (Cyath. simplex, Phil.; Phœnicocrinites, Austin)					*		
tuberculatus, Mill., **Pl. 14.** f. 5					*		
TETRAGONIS Danbyi, M'Coy, Pal. Fos. p. 62						*	
TETRAMEROCRINUS formosus, Aust. A. N. H. 1843, p. 203				?	*		
TROCHOCRINUS (see Glyptocrinus).							
ANNELIDA.							
APHRODITA, Portl. Geol. Rep. p. 362			*				
ARENICOLITES linearis, Hall, sp., **Foss. 3**		*					
CHONDRITES? acutangulus, M'Coy, Pal. Fos. t. 1 A	*						
CHONDRITES? informis, M'Coy, Pal. Fos. t. 1 A	*						
CORNULITES serpularius, Schl., **Pl. 16.** f. 3, 10; **Pl. 10.** f. 2				*	*	*	
CROSSOPODIA lata, M'Coy, Pal. Fos. p. 130						*	

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
CROSSOPODIA Scotica, M'Coy, **Foss. 42.** f. 4	.....	.....	*				
LUMBRICARIA antiqua, Portl. Geol. Rep. p. 361	.....	.....	*				
gregaria, Portl. Geol. Rep. p. 361	.....	.....	*				
MYRIANITES Macleayi, Murch., **Foss. 42.** f. 1	.....	*					
tenuis, M'Coy, Pal. Fos. p. 130	.....	.....	*				
NEMERTITES Ollivantii, Murch. Sil. Syst. p. 701	.....	*					
NEREITES Cambrensis, Murch., **Foss. 42.** f. 3	.....	*					
multiforis, Harkn. G. J. xi. p. 476	.....	*					
Sedgwickii, Murch., **Foss. 42.** f. 2	.....	*					
SERPULITES curtus, Salt. Mem. G. S. ii. p. 333	.....	.....	.....	.....	*		
dispar, Salt. Pal. Fos. App. p. i.	.....	.....	.....	.....	.....	*	
longissimus, Murch., **Pl. 16.** f. 1	.....	.....	.....	.....	*	*	
? MacCullochii, Salt., **Foss. 43**	.....	*					
perversus, M'Coy, G. J. ix. p. 15	.....	.....	.....	.....	*		
SPIRORBIS Lewisii, Sow., **Pl. 16.** f. 2	.....	.....	.....	.....	*	*	
TENTACULITES Anglicus, Salt., **Pl. 1.** f. 3; **10.** f. 3; **Foss. 12.** f. 4	.....	.....	*	*			
ornatus, Sow., **Pl. 16.** f. 11	.....	.....	*	*	*		
tenuis, Sow., **Pl. 16.** f. 12	.....	.....	.....	.....	.....	*	
TRACHYDERMA antiquissima, Salter, Malvern Proc. pt. 1	.....	*					
coriacea, Phil. Mem. G. S. ii. p. 331	.....	.....	.....	.....	.....	*	
lævis, M'Coy, Pal. Fos. p. 133	.....	.....	*				
squamosa, Phil. Mem. G. S. ii. p. 332	.....	.....	.....	.....	.....	*	
CRUSTACEA.							
ACIDASPIS Barrandii, Fletch., **Foss. 64.** f. 9	.....	.....	.....	.....	*		
bispinosa, M'Coy, **Foss. 46.** f. 6	.....	.....	*				
Brightii, Murch., **Foss. 64.** f. 8; **Pl. 18.** f. 7, 8	.....	.....	*	*	*		
callipareos, Thoms. G. J. xiii. p. 208	.....	.....	.....	*			
Caractaci, Salt. G. J. xiii. p. 211	.....	.....	*				
coronata, Salt. G. J. xiii. p. 210	.....	.....	.....	.....	.....	*	
crenata, Emm. sp.	.....	.....	.....	.....	*		
Dama, Fletch. and Salt., Morris Cat. p. 99	.....	.....	.....	.....	*		
dumetosa, Fletch. and Salt., Morris Cat. p. 99	.....	.....	.....	.....	*		
hystrix, Thoms. G. J. xiii. p. 207	.....	.....	*				
Jamesii, Salt. Dec. 7. t. 6	.....	.....	*				
Lalage, Thoms. G. J. xiii. p. 206	.....	.....	*				
quinquespinosa, Fletch. & Salt., Morris Cat. p. 99	.....	.....	.....	.....	*		
unica, Thoms. G. J. xiii. p. 209	.....	.....	*				
ÆGLINA binodosa, Salt., **Foss. 8.** f. 6	.....	*					
grandis, Salt., **Foss. 9.** f. 6	.....	*					
major, Salt. Dec. G. S. 7. pl. 10. p. 4	.....	*					
mirabilis, Forbes, **Foss. 26.** f. 3	.....	.....	*				
AGNOSTUS limbatus, Salt. MS. (trinodus, part., M. G. S. vol. ii. pt. 1. pl. 8. f. 11)	.....	.....	*				
Maccōyi, Salt., **Foss. 10.** f. 5; **Pl. 3.** f. 7, 8	.....	*					
pisiformis, Brong., **Foss. 4.** f. 4; **9.** f. 9	*	*					
trinodus, Salt., **Foss. 44.** f. 6	.....	.....	*				
n. sp., **Foss. 9.** f. 10. **p. 53**	.....	*					
AMPHION pseudoarticulatus, Portl. Geol. Rep. p. 291	.....	.....	*				
AMPYX mammillatus, Sars, ib. p. 261	.....	.....	*				
nudus, Murch., **Foss. 46.** f. 7; **Pl. 4.** f. 9, 10	.....	*					

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
AMPYX parvulus, Forbes, Mem. G. S. p. 350					*	*	
rostratus, Sars, Portl. G. R. p. 260			*				
tumidus, Forbes, Dec. G. S. 2			*				
ANGELINA Sedgwickii, Salt., **Foss. 9.** f. 2		*					
subarmata, Salt., **Foss. 9.** f. 3		*					
ASAPHUS gigas, DeKay, **Foss. 26.** f. 1			*				
læviceps, Portl. sp., Geol. Rep. p. 299			*				
laticostatus, Green, Pal. Fos. p. 170		*					
Powisii, Murch., **Foss. 44.** f. 1; **Pl. 2.** f. 2			*				
rectifrons, Portl. Geol. Rep. p. 298			*				
Selwynii, Salt. MS. (see Ogygia).							
tyrannus, Murch., **Foss. 10.** f. 1; **Pl. 1.** f. 4, 5; **2.** f. 1		*					
BEYRICHIA affinis, Jones, Ann. N. H. s. 2. xvi. p. 170			*				
Barrandiana, Jones, Ann. N. H. xvi. p. 171			*				
bicornis, Jones, Ann. N. H. xvi. p. 173			*				
complicata, Salt., **Foss. 10.** f. 10*a*; **44.** f. 7		*	*				
Klœdeni, M'Coy, **Foss. 63.** f. 4; **Pl. 34.** f. 21				*	*	*	*
seminulum, Jones, Ann. N. H. xvi. p. 173					*		
siliqua, Jones, Ann. N. H. xvii. p. 90					*	*	
strangulata, Salt. Pal. Fos. App. p. ii.			*				
BRONTEUS Hibernicus, Portl. Geol. Rep. p. 270			*				
laticauda, Wahl. sp.			*		*		
CALYMENE Blumenbachii, Brong., **Foss. 12.** f. 1; **Pl. 17.** f. 1; **18.** f. 10			*	*	*	*	
brevicapitata, Portl., **Foss. 10.** f. 9; **44.** f. 4		*	*				
duplicata, Murch., **Foss. 10.** f. 10; **Pl. 3.** f. 6		*					
obtusa (Otarion), M'Coy, Sil. Fos. p. 54			*				
parvifrons, Salt., **Foss. 9.** f. 4		*					
tuberculosa, Salt., **Foss. 63.** f. 2; **Pl. 18.** f. 11					*	*	
CERATIOCARIS (+Leptocheles) ellipticus, M'Coy, Pal. Fos. p. 137						*	
inornatus, M'Coy, Pal. Fos. p. 137						*	
leptodactylus, M'Coy, Pal. Fos. p. 175						*	
Murchisoni, Ag., **Pl. 19.** f. 1, 2						*	
papilio, Salt., **Foss. 65. p. 262**						*	
5 other species						*	
CHEIRURUS bimucronatus, Murch., **Foss. 64.** f. 4; **Pl. 3.** f. 5; **19.** f. 10, 11			*	*	*		
cancrurus, Salt. Dec. G. S. 7			*				
clavifrons, Dalm., **Foss. 46.** f. 1			*				
gelasinosus, Portl. sp., Geol. Rep. p. 289			*				
octolobatus, M'Coy, Pal. Fos. p. 154			*				
Sedgwickii, M'Coy, Pal. Fos. p. 155		*					
CONOCEPHALUS invitus, Salt., **Foss. 7.** f. 1	*						
CYBELE rugosa, Portl. sp., Geol. Rep. p. 302			*				
verrucosa, Dalm., **Foss. 46.** f. 2		*	*				
CYPHASPIS megalops, M'Coy, **Foss. 64.** f. 2			*	*	*	*	
pygmæus, Salt. Dec. G. S. 7					*		
CYPHONISCUS socialis, Salt., **Foss. 46.** f. 8			*				
CYTHERE ? umbonata, Salt. Pal. Fos. App. p. ii.			*				
? phaseolus, M'Coy (not of Hisinger)			*				

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
CYTHEROPSIS Aldensis, M'Coy, Pal. Fos. pl. 1 L. f. 2	.....	.....	*				
DEIPHON Forbesii, Barr. S. S. Bohem. p. 814	.....	.....	.....	.....	*		
DITHYROCARIS ? aptychoides, Salt. G. J. viii. p. 391	.....	*					
ELLIPSOCEPHALUS depressus, Salt., **Foss. 7.** f. 2	*						
ENCRINURUS baccatus, Portl. sp., Geol. Rep. p. 262	.....	.....	*				
multisegmentatus, Portl. Geol. Rep. p. 291	.....	.....	*				
punctatus, Brünn., **Foss. 14.** f. 10; **64.** f. 5; **Pl. 10.** f. 5	.....	.....	.....	*	*	*	
sexcostatus, Salt. Dec. G. S. 7. t. 4	.....	.....	*				
variolaris, Brongn., **Foss. 64.** f. 6; **Pl. 18.** f. 9	.....	.....	.....	.....	*		
EURYPTERUS abbreviatus, Salt. G. J. vol. xv.	.....	.....	.....	.....	.....	*	
acuminatus, Salt. G. J. vol. xv.	.....	.....	.....	.....	.....	.....	*
cephalaspis, Salt. Pal. Fos. App. p. v.	.....	.....	.....	.....	.....	*	
chartarius, Salt. G. J. vol. xv.	.....	.....	.....	.....	.....	*	
lanceolatus, Salt. Dec. G. S. 10. pl. 1. f. 17	.....	.....	.....	.....	.....	*	
linearis, Salt. G. J. vol. xv.	.....	.....	.....	.....	.....	*	*
megalops, Salt. G. J. vol. xv.	.....	.....	.....	.....	.....	.....	*
pygmæus, Salt., **Foss. 66.** f. 1	.....	.....	.....	.....	.....	*	*
HARPES Dorani, Portl. Geol. Rep. p. 267	.....	.....	*				
Flanagani, Portl., **Foss. 46.** f. 4	.....	.....	*				
HOMALONOTUS bisulcatus, Salt., **Foss. 9.** f. 5; **12.** f. 2	.....	.....	*	*			
delphinocephalus, Green, **Foss. 16.** f. 1	.....	.....	.....	.....	*		
Knightii, König, **Pl. 19.** f. 7–9	.....	.....	.....	.....	.....	*	
rudis, Salt. Pal. Fos. p. 168	.....	.....	*				
Vulcani, Murch., **Pl. 2.** f. 3, 4	.....	*					
HYMENOCARIS vermicauda, Salt., **Foss. 5.** f. 1	*						
ILLÆNUS Barriensis, Murch., **Pl. 17.** f. 9–11	.....	.....	.....	.....	*		
Bowmanni, Salt. Dec. G. S. 2	.....	.....	*	*			
Davisii, Salt., **Foss. 44.** f. 2	.....	.....	*				
Murchisoni, Salt. Dec. G. S. 2	.....	*					
ocularis, Salt. Dec. G. S. 2	.....	.....	*				
perovalis, Murch., **Pl. 4.** f. 13, 14; **23.** f. 7	.....	*					
Portlockii, Salt. Dec. G. S. 2	.....	.....	*				
LEPERDITIA marginata, Keys.? Ann. N. H. xvii. p. 91	.....	.....	.....	.....	.....	*	*
Solvensis, Jones, Ann. N. H. xvii. p. 95.	.....	*					
LICHAS Anglicus, Beyr., **Foss. 63.** f. 1	.....	.....	.....	.....	*	*	
Barrandii, Fletch., **Foss. 63.** f. 3	.....	.....	.....	.....	*		
Grayii, Fletch. G. J. vi. p. 237	.....	.....	*	.....	*		
hirsutus, Fletch. G. J. vi. p. 236	.....	.....	.....	.....	*		
laciniatus, Dalm. Pal. Fos. App. p. iv.	.....	.....	*				
laxatus, M'Coy, **Foss. 44.** f. 5	.....	.....	*	*			
nodulosus, Salt. Pal. Fos. App. p. iv	.....	.....	*				
Salteri, Fletch. G. J. vi. p. 237	.....	.....	.....	.....	*		
verrucosus, Eichw. M. G. S. ii. p. 340	.....	.....	.....	.....	*		
LIMULOIDES, sp. M'Coy, Pal. Fos. pl. 1 *e*. f. 12	.....	.....	.....	.....	.....	*	
2 other species	.....	.....	.....	.....	.....	*	
OGYGIA Buchii, Brongn., **Foss. 10.** f. 2; **Pl. 3.** f. 1, 2	.....	*					
Corndensis, Murch., **Pl. 3.** f. 4	.....	*					
Portlockii, Salt., **Foss. 10.** f. 3	.....	*					
scutatrix, Salt., **Foss. 9.** f. 1	.....	*					
Selwynii, Salt., **Foss. 9.** f. 8	.....	*					
OLENUS alatus, Beck (Angelin, Pal. Suec. pt. i.)	*						
bisulcatus, Phil., **Foss. 6.** f. 2	.....	.....	*?				
humilis, Phil., **Foss. 6.** f. 1	.....	.....	*?				
micrurus, Salt., **Foss. 4.** f. 2	*						

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
Olenus scarabæoides, Salt., **Foss. 6.** f. 3 (O. spinulosus, Phil.)			*?				
Paradoxides Forchhammeri, Ang., **Foss. 5.** f. 2	*						
Phacops alifrons, Salt. Pal. Fos. App. p. ii.			*				
amphora, Salt. Dec. G. S. 7. p. 12			*				
apiculatus, Salt., **Foss. 13.** f. 3			*				
Brongniartii, Portl. Geol. Rep. p. 282			*				
caudatus, Brongn., **Pl. 17.** f. 2; **18.** f. 1				*	*	*	
conophthalmus, Boeck, **Foss. 46.** f. 3; **Pl. 4.** f. 11, 12			*				
Dalmanni, Portl. Geol. Rep. p. 282			*				
Downingiæ, Murch., **Foss. 64.** f. 3; **Pl. 18.** f. 2					*	*	
Jamesii, Portl. Geol. Rep. p. 283			*				
Jukesii, Salt. Dec. G. S. 7. p. 11			*				
longicaudatus, Murch., **Pl. 17.** f. 3–6					*	*	
mucronatus, Brongn. Dec. G. S. 7			*				
obtusicaudatus, Salt. Dec. G. S. 7			*				
Stokesii, Edw., **Pl. 10.** f. 6; **18.** f. 6				*	*		
sublævis, M'Coy, Sil. Fos. Irel. p. 51				*			
truncatocaudatus, Portl., **Foss. 12.** f. 3			*				
Weaveri, Salt. Dec. G. S. 2. p. 7				*	*?		
Proetus latifrons, M'Coy, **Foss. 64.** f. 7				*	*	*	
Stokesii, Murch., **Pl. 17.** f. 7					*		
Protichnites Scoticus, Salt., **Foss. 23. p. 168**	*						
Pterygotus acuminatus, Salt., **Foss. 25.** f. 6						*	
Anglicus, Ag., **Foss. 21.** f. 1							*
arcuatus, Salt. Dec. G. S. 10. pl. 13. f. 5						*	
gigas, Salt. Dec. G. S. 10. pl. 9						*	*?
Ludensis, Salt. Dec. G. S. 10. pl. 14							*
problematicus, Ag. Dec. G. S. 10. pl. 12. f. 9						*	
punctatus, Salt. Dec. G. S. 10. pl. 10–13.						*	
stylops, Salt. Dec. G. S. 10. pl. 12. f. 4–7						*	
sp., **Pl. 10.** f. 4				*			
(Subgenus Himantopterus.)							
Banksii, Salt. Dec. G. S. 10. pl. 12. f. 25.						*	*
bilobus, Salt., **Foss. 25.** f. 1						*	
perornatus, Salt. Dec. G. S. 10. pl. 1. f. 13						*	
var. plicatissimus, Salt. id. pl. 1. f. 16.						*	
Parka decipiens, Flem. (eggs of Pterygotus?)							*
Remopleurides Colbii, Portl. Geol. Rep. p. 256.			*				
dorso-spinifer, Portl., **Foss. 46.** f. 5			*				
latero-spinifer, Portl. Geol. Rep. p. 256			*				
longi-costatus, Portl. Geol. Rep. p. 257			*				
obtusus, Salt. Dec. G. S. 7. p. 9			*				
platyceps, M'Coy, Sil. Fos. p. 44			*				
radians, Barr. S. S. Bohem. p. 32			*				
Sphærexochus mirus, Beyr., **Foss. 64.** f. 1			*	?	*		
sp.			*				
Staurocephalus globiceps, Portl. Geol. R. p. 257			*				
Murchisoni, Barr. S. S. Bohem. p. 812.			*		*		
Stygina latifrons, Portl., **Foss. 26.** f. 2			*				
Murchisonæ, Murch., **Foss. 10.** f. 4; **Pl. 4.** f. 1		*					
Tiresias insculptus, M'Coy, Sil. Fos. p. 43			*				
Trinucleus concentricus, Eaton, **Foss. 10.** f. 8; **44.** f. 3; **45**; **Pl. 4.** f. 2–5		*	*	*??			

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
TRINUCLEUS fimbriatus, Murch., **Foss. 10.** f. 6; **Pl. 4.** f. 7		*					
Gibbsii, Salt., **Foss. 9.** f. 7		*					
Lloydii, Murch., **Foss. 10.** f. 7; **Pl. 4.** f. 6		*					
Murchisonii, Salt., **Foss. 8.** f. 7		*					
radiatus, Murch., **Pl. 4.** f. 8		*					
seticornis, His., **Foss. 13.** f. 1, 2			*				
Thersites, Salt. Dec. G. S. 7			*				
BRYOZOA (or POLYZOA).							
CELLEPORA favosa, Goldf. Pet. p. 217					*		
CERIOPORA affinis, Goldf. Pet. p. 216					*		
granulosa, Goldf., **Pl. 41.** f. 29					*		
DIASTOPORA heterogyra, M'Coy, Pal. Foss. p. 45			*				
irregularis (Berenicea, Lons.), **Pl. 41.** f. 20					*		
DICHOGRAPSUS Sedgwicki, Salt. MS.		*					
DICTYONEMA (Graptopora) sociale, Salt., **Foss. 7.** f. 3	*						
DIDYMOGRAPSUS caduceus, Salt. Geol. Jour. ix. p. 87			*				
geminus, His., **Foss. 8.** f. 8		*					
Murchisonii, Beck, **Foss. 10.** f. 13; **11.** f. 9; **Pl. 1.** f. 1		*					
sextans, Hall, **Foss. 11.** f. 8		*					
DIPLOGRAPSUS bullatus, Salt. Geol. Jour. vii. p. 174			*				
foliaceus, Murch., **Pl. 1.** f. 2		*					
folium, His., **Foss. 11.** f. 6		*					
mucronatus, Hall, Pal. N. Y. p. 268		*					
nodosus, Harkn., **Foss. 11.** f. 5		*					
pennatus, Harkn. Geol. Journ. vii. p. 62		*					
pristis, His. sp., **Foss. 11.** f. 4; **12.** f. 14		*	*				
ramosus, Hall, sp., **Foss. 11.** f. 7		*					
rectangularis, M'Coy, Pal. Foss. p. 8		*					
teretiusculus, His. sp., **Foss. 10.** f. 14		*	*				
DISCOPORA antiqua, Lam., **Pl. 41.** f. 21					*		
? favosa, Lons., **Pl. 41.** f. 22					*		
squamata, Lons., **Pl. 41.** f. 23					*		
ESCHARINA? angularis, Lons., **Pl. 41.** f. 10					*		
FENESTELLA assimilis,, Lons., **Foss. 49.** f. 2; **Pl. 41.** f. 27			*		*		
capillaris, Portl. Geol. Rep. p. 323			*				
Lonsdalei, d'Orb., **Foss. 49.** f. 3. (F. prisca, Lons., **Pl. 41.** f. 15–18)					*		
Milleri, Lons., **Foss. 49.** f. 4; **Pl. 41.** f. 17			*		*		
patula, M'Coy, Pal. Foss. p. 50					*		
regularis, Portl. Geol. Rep. p. 323			*				
reticulata, Lons., **Pl. 41.** f. 19					*		
rigidula, M'Coy, Pal. Foss. p. 50					*		
subantiqua, d'Orb., **Foss. 27.** f. 1. (F. antiqua, Lons., **Pl. 41.** f. 16)			*		*		
undulata, Portl. Geol. Rep. p. 322			*				
GLAUCONOME disticha, Goldf., **Foss. 49.** f. 5; **Pl. 41.** f. 12			*		*		
GRAPTOLITHUS Conybeari, Portl. G. J. viii. p. 391			*				
Flemingii, Salt. Geol. Journ. viii. p. 390					*?		
Griestonensis, Nicol, Geol. Jour. vi. p. 63			*				
latus, M'Coy, Pal. Foss. p. 4		*					
lobiferus, M'Coy, **Foss. 10.** f. 11		*					
Nicoli, Harkn. Geol. Journ. vii. p. 61		*					

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
GRAPTOLITHUS Nilssoni, Barr. Geol. Journ. vii. p. 61		*					
priodon, Bronn (G. Ludensis), **Foss. 11.** f. 3; **12.** f. 15; **Pl. 12.** f. 1			*	*	*	*	
sagittarius, Linn. Geol. Jour. viii. p. 390		*					
Sedgwickii, Portl., **Foss. 11.** f. 2		*	*				
tenuis, Portl., **Foss. 10.** f. 12			*				
HETEROPORA ? crassa, Lons., **Pl. 41.** f. 14					*		
INTRICARIA obscura, Portl. Geol. Rep. p. 326			*				
NIDULITES favus, Salt., **Foss. 27.** f. 3				*			
PHYLLOPORA ? (Retepora) Hisingeri, M'Coy, **Foss. 28.** f. 6			*				
POLYPORA ? crassa, Lons., **Foss. 49.** f. 1; **Pl. 41.** f. 13. (Hornera, Sil. Syst.)					*		
PROTOVIRGULARIA dichotoma, M'Coy, Pal. Fos. p. 10		*					
PTILODICTYA acuta, Hall, sp., **Foss. 27.** f. 2			*				
costellata, M'Coy, Pal. Fos. p. 46			*				
dichotoma, Portl., **Foss. 28.** f. 5			*	*			
explanata, M'Coy, Pal. Fos. p. 46			*				
fucoides, M'Coy, Pal. Fos. p. 47			*				
lanceolata, Lons., **Foss. 49.** f. 6; **Pl. 41.** f. 11			*	*	*		
scalpellum, Lons., **Foss. 50**; **Pl. 41.** f. 25				*	*		
RASTRITES Barrandii, Harkn. Geol. J. xi. p. 475		*					
peregrinus, Barr., **Foss. 11.** f. 1		*					
RETEPORA ? infundibulum, Lons., **Pl. 41.** f. 24					*		
RETIOLITES Geinitzianus, Barr. Grapt. Boh. p. 69					*		
venosus, Hall, Pal. N. York, ii. p. 40					*		
[AULOPORA consimilis, Lons., **Pl. 41.** f. 7, belongs to the Bryozoa: prob. Diastopora ?, Lons.]							
BRACHIOPODA.							
ATHYRIS Circe, Barrande, Bull. S. Géol. Fr. v. p. 326					*		
?obovata, Sow., **Pl. 22.** f. 16					*	*	
tumida, Dalm., **Pl. 22.** f. 20				*	*		
ATRYPA ? crassa, Sow., **Pl. 9.** f. 6–8				*			
hemisphærica, Sow., **Foss. 14**; **Pl. 9.** f. 3				*			
marginalis, Dalm., **Pl. 9.** f. 2; **22.** f. 19			*	*	*		
orbicularis (var. of A. reticularis), Sow., **Pl. 9.** f. 4, 5				*	*		
reticularis, Linn., **Foss. 14.** f. 5; **Pl. 9.** f. 1; **21.** f. 12, 13				*	*	*	
CHONETES lata, von Buch, **Pl. 20.** f. 8; **34.** f. 18				*?	*	*	
CRANIA craniolaris, M'Coy, sp., Pal. Fos. p. 255					*		
divaricata, M'Coy, sp., **Foss. 35.** f. 2			*				
Sedgwickii, Dav. Bul. S. Géol. Fr. v. p. 334					*		
DISCINA (Orbicula) crassa, Hall, Pal. N. Y. i. p. 290			*				
Forbesii, Dav., **Foss. 57.** f. 11					*		
implicata, Sow., **Pl. 20.** f. 4				*	*	*	
lævigata, Münst. ? Geol. Rep. p. 345			*				
Morrisii, Dav. Bul. S. G. Fr. v. p. 334					*		
oblongata, Portl. Geol. Rep. p. 445			*				
perrugata, M'Coy, Sil. Fos. p. 24			*				
punctata, **Foss. 35.** f. 1; **Pl. 5.** f. 17			*				
rugata, Sow., **Pl. 20.** f. 1, 2; **35.** f. 27					*	*	
striata, Sow., **Pl. 20.** f. 3						*	
subrotunda, Portl. Geol. Rep. p. 445			*				

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
DISCINA Verneuilii, Dav. Bul. S. G. Fr. v. p. 334	.....	.....	.....	.....	*		
LEPTÆNA Fletcheri, Dav. (see L. transversalis).							
lævigata, Sow., **Pl. 20.** f. 15	.....	.....	.....	.....	*	*	
lævissima, M'Coy, Sil. Fos. p. 27	.....	.....	.....	.....	*		
minima, Sow., **Pl. 20.** f. 16	.....	.....	.....	*	*		
quinquecostata, M'Coy, **Foss. 34.** f. 3.	.....	.....	*				
scissa, Salt., **p. 231**	.....	.....	.....	*			
sericea, Sow., **Foss. 33.** f. 6; **Pl. 5.** f. 14; **9.** f. 18	.....	*	*	*	*?		
sublævis, M'Coy, Sil. Fos. p. 35	.....	.....	*				
tenuicincta, M'Coy, **Foss. 34.** f. 4	.....	*	*				
transversalis, Dalm., **Pl. 9.** f. 17; **20.** f. 17 (L. Duvalii and L. Fletcheri, Dav. Bul. S. G. Fr. v. p. 317, 319)	.....	.....	*	*	*		
ungula, M'Coy, Pal. Fos. p. 249	.....	.....	*				
LINGULA attenuata, Sow., **Foss. 10.** f. 18; **Pl. 5.** f. 16	.....	*					
brevis, Portl. Geol. Rep. p. 443	.....	.....	*				
cornea, Sow., **Foss. 22.** f. 3; **25.** f. 8; **Pl. 34.** f. 2	.....	.....	.....	.....	.....	*	*
crumena, Phil., **Foss. 12.** f. 5	.....	.....	.....	*			
Davisii, M'Coy, **Foss. 4.** f. 1; **9.** f. 11	*						
granulata, Phil., **Foss. 10.** f. 19; **35.** f. 4	.....	*					
lata, Sow., **Pl. 20.** f. 6	.....	.....	.....	.....	.....	*	
lepis, Salt. MS.	*						
Lewisii, Sow., **Pl. 20.** f. 5	.....	.....	.....	.....	*	*	
longissima, Pand.? Pal. Fos. p. 252	.....	.....	*				
obtusa, Hall, Pal. N. York, p. 98	.....	*					
ovata, M'Coy, Sil. Fos. p. 24	.....	.....	*				
parallela, Phil. Mem. G. S. ii. pt. 1. p. 370	.....	.....	.....	*			
plumbea, Salt., **Foss. 8.** f. 1	.....	*					
Ramsayi, Salt., **Foss. 10.** f. 20	.....	*					
striata, Sow., **Pl. 20.** f. 7	.....	.....	.....	.....	.....	*	
tenuigranulata, M'Coy, **Foss. 35.** f. 5.	.....	.....	*				
OBOLUS Davidsoni, Salt., Dav. Clas. Brach. p. 136	.....	.....	.....	*	*		
transversus, Salt., Dav. Clas. Brach. p. 136	.....	.....	.....	.....	*		
ORTHIS Actoniæ, Sow., **Foss. 32.** f. 2; **Pl. 5.** f. 11	.....	*	*	*			
æquivalvis, Dav. Bul. S. G. Fr. v. p. 321	.....	.....	.....	*			
alata, Sow. sp., **Foss. 10.** f. 15; **Pl. 5.** f. 6	.....	*					
alternata, Sow., **Pl. 6.** f. 5	.....	.....	*				
biforata, Schl., **Foss. 33.** f. 4; **34.** f. 1.	.....	*	*	*	*		
biloba, Linn., **Pl. 9.** f. 20; **20.** f. 14	.....	.....	*	*	*		
Bouchardii, Dav., **Foss. 58.** f. 1	.....	.....	.....	*	*		
calligramma, Dalm., **Foss. 9.** f. 12; **Pl. 5.** f. 7-9; **9.** f. 21; **20.** f. 10	.....	*	*	*	*		
confinis, Salt. G. J. v. p. 15	.....	.....	*				
costata, Sow. Sil. Syst. p. 639	.....	.....	*				
crispa, M'Coy, Sil. Fos. p. 29	.....	.....	*	?			
Davidsoni, Vern., **Foss. 58.** f. 2	.....	.....	.....	*	*		
elegantula, Dalm., **Pl. 5.** f. 5; **9.** f. 19; **20.** f. 12	.....	*	*	*	*	*	
var. orbicularis, **Pl. 20.** f. 9	.....	.....	.....	.....	*	*	
fallax, Salt. Sil. Fos. p. 72	.....	.....	*				
flabellulum, Sow., **Foss. 32.** f. 1; **Pl. 5.** f. 12	.....	.....	*				
Hirnantensis, M'Coy, Pal. Fos. p. 219	.....	.....	*				
hybrida, Sow., **Pl. 20.** f. 13	.....	.....	*	*?	*		
insularis, Eichw. Geol. Russ. ii. pl. 8. f. 7	.....	.....	*	*			
intercostata, Portl. Geol. Rep. p. 454	.....	.....	*				

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
ORTHIS interplicata, M'Coy, Sil. Fos. p. 31			*				
lata, Sow., **Pl. 9.** f. 22, 23				*			
Lewisii, Dav. Bul. S. G. Fr. v. p. 323					*		
lunata, Sow., **Pl. 20.** f. 11; **35.** f. 29						*	
porcata, M'Coy, **Foss. 33.** f. 5			*		*		
? productoides, M'Coy, Sil. Fos. p. 32			*				
radians, Sow., **Pl. 5.** f. 10			*				
remota, Salt., **Foss. 9.** f. 13	*						
reversa, Salt., **Foss. 48.** f. 3				*			
rustica, Sow. Sil. Syst. p. 624					*		
sagittifera, M'Coy, Pal. Fos. p. 227			*	*?			
semicircularis, Sow. Sil. Syst. p. 639			*				
simplex, M'Coy, Sil. Fos. p. 34			*				
spiriferoides, M'Coy., **Foss. 34.** f. 2		*	*				
striatula, Emmons, **Foss. 10.** f. 16; **33.** f. 3		*					
testudinaria, Dalm., **Foss. 12.** f. 6; **Pl. 5.** f. 1, 2			*	*			
triangularis, Sow., **Pl. 5.** f. 13		*					
tricenaria, Conrad, Hall, Pal. N.Y. i. p. 121			*				
turgida, M'Coy, Pal. Fos. p. 229		*	*				
unguis, Sow., **Pl. 5.** f. 3, 4			*				
vespertilio, Sow., **Foss. 12.** f. 7; **Pl. 6.** f. 1–3			*	*?			
ORTHISINA ascendens, Pand. Pal. Fos. p. 231			*				
Scotica, M'Coy, Pal. Fos. p. 232			*				
PENTAMERUS galeatus, Dalm., **Pl. 21.** f. 8, 9					*	*	
globosus, Sow., **Pl. 8.** f. 8				*			
Knightii, Sow., **Pl. 21.** f. 10, var. f. 11					*	*	
lævis, Sow., var. of P. oblongus				*			
lens, Sow., **Foss. 14.** f. 1; **47.** f. 1; **Pl. 8.** f. 9–11				*			
linguifer, Sow., **Pl. 22.** f. 21				*?	*		
liratus, Sow., **Foss. 14.** f. 3; **47.** f. 3				*	*		
oblongus, Sow., **Foss. 14.** f. 2; **47.** f. 1; **Pl. 8.** f. 1–4				*			
undatus, Sow., **Foss. 14.** f. 6; **47.** f. 6; **Pl. 8.** f. 5–7				*			
PORAMBONITES? Capewellii, Dav., **Foss. 57.** f. 4					*		
intercedens, Pand. Beitr. t. 11. f. 2				*			
RETZIA Barrandei, Dav. Bul. S. G. Fr. 2 sér. v. p. 332					*		
Baylei, Dav., **Foss. 57.** f. 9					*		
Bouchardii, Dav., **Foss. 57.** f. 5					*		
cuneata, Dalm., **Pl. 22.** f. 8					*		
Lewisii, Dav. Bul. S. G. Fr. v. p. 230					*		
Salteri, Dav., **Foss. 57.** f. 7, 8					*		
RHYNCHONELLA angustifrons, M'Coy, **Foss. 48.** f. 2				*			
borealis, Schl., **Pl. 22.** f. 4, var. f. 5				*	*	*?	
brevirostrum, Sow. Sil. Syst. p. 631					*		
compressa, Sow., **Pl. 22.** f. 22					*		
crebricosta, Sow., **Pl. 22.** f. 7					*		
crispata, Sow., **Pl. 22.** f. 6					*		
Davidsoni, M'Coy, Pal. Fos. p. 200						*	
decemplicata, Sow., **Pl. 9.** f. 15				*	*		
deflexa, Sow., **Pl. 22.** f. 10					*		
depressa, Sow., **Pl. 22.** f. 17			*		*		
didyma, Dalm., **Pl. 22.** f. 15				*	*	*	

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
RHYNCHONELLA furcata, Sow., **Pl. 9.** f. 12, 13			*				
Grayii, Dav., **Foss. 57.** f. 3			*	*			
interplicata, Sow. Sil. Syst. p. 631				*			
Lewisii, Dav., **Foss. 57.** f. 2				*	*		
nasuta, M'Coy, Pal. Fos. p. 203			*				
navicula, Sow., **Pl. 22.** f. 12					*	*	
neglecta, Sow., **Pl. 9.** f. 14				*			
nitida, Hall, Pal. N. York, p. 268					*		
nucula, Sow., **Foss. 57.** f. 1; **Pl. 9.** f. 9; **22.** f. 1, 2				*	*	*	
obtusiplicata, Hall, Pal. N. York, p. 269				*			
pentagona, Sow., **Pl. 22.** f. 3						*	
pusilla, Sow., **Pl. 9.** f. 11				*			
rotunda, Sow., **Pl. 22.** f. 18					*		
serrata, M'Coy, **Foss. 48.** f. 1				*			
sexcostata, M'Coy, Sil. Fos. p. 41				*			
sphærica, Sow., **Pl. 22.** f. 9					*		
sphæroidalis, M'Coy, Pal. Fos. p. 206					*		
Stricklandi, Sow., **Pl. 22.** f. 11					*		
subundata, M'Coy, Pal. Fos. p. 207				*			
tripartita, Sow., **Pl. 9.** f. 10				*			
upsilon, Barr. Sil. Brach. t. 15			*				
Wilsoni, Sow., **Pl. 22.** f. 13				*	*	*	
SIPHONOTRETA Anglica, Morr., **Foss. 57.** f. 10					*		
micula, M'Coy, **Foss. 10.** f. 17; **36.** f. 3		*					
SPIRIFER crispus, Linn., **Pl. 21.** f. 4				*	*	*	
elevatus, Dalm., **Pl. 21.** f. 5, 6				*	*	*	
insularis, Eichw., Geol. Russ. ii. p. 149		*	*				
? pisum, Sow., **Pl. 21.** f. 7					*		
plicatellus, Sow., **Pl. 9.** f. 25; **21.** f. 1, 2				*	*	*	
trapezoidalis, Dalm., **Pl. 9.** f. 24; **21.** f. 3				*	*	*	
STROPHOMENA alternata, Conr. Pal. N. York, p. 102 (bipartita, Salt., included)			*	*			
antiquata, Sow., **Foss. 58.** f. 8; **Pl. 20.** f. 18			*	*	*		
applanata, Salt. M. G. S. ii. p. 380				*	*		
arenacea, Salt., p. 231				*			
complanata, Sow. Sil. Syst. p. 636			*				
compressa, Sow., **Foss. 14.** f. 7; **47.** f. 7; **Pl. 9.** f. 16				*			
concentrica, Portl. Geol. Rep. p. 452			*				
corrugata, Portl. Geol. Rep. p. 450			*	*			
deltoidea, Conr. Pal. N. York, p. 106			*				
depressa, Dalm., **Pl. 20.** f. 20			*	*	*	*	
euglypha, Dalm., **Pl. 20.** f. 19				*	*	*	
expansa, Sow., **Foss. 33.** f. 2; **Pl. 6.** f. 4			*				
filosa, Sow. Sil. Syst. p. 630					*	*	
funiculata, M'Coy, **Foss. 58.** f. 4, 5				*	*		
grandis, Sow., **Foss. 12.** f. 9; **Pl. 6.** f. 6, 7 (cancellata, Portl. Geol. Rep. p. 450)			*				
imbrex, Pand., **Foss. 58.** f. 6, 7					*		
Ouralensis, Vern. Geol. Russ. t. 14					*		
Pecten, Linn., **Foss. 58.** f. 3			*	*	*		
simulans, M'Coy, Pal. Fos. p. 246			*				
tenuistriata, Sow., **Foss. 12.** f. 8; **Pl. 5.** f. 15			*				
undata, M'Coy, Pal. Fos. p. 234					*		
TEREBRATULA ? læviuscula, Sow., **Pl. 22.** f. 14					*		
TREMATIS punctata, Sow. sp., Sil. Syst. p. 636			*				

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
LAMELLIBRANCHIATA.							
(Monomyaria.)							
AMBONYCHIA acuticosta, M'Coy, Pal. Fos. p. 264.	.....	.....	.....	.....	*		
carinata, Conr., Hall, Pal. New York, i. p. 294	.....	.....	*				
gryphus, Portl. Geol. Rep. p. 455	.....	.....	*				
transversa, Portl. Geol. Rep. p. 746	.....	.....	*				
trigona, Portl. Geol. Rep. p. 422	.....	.....	*				
Triton, Salt. sp., **Foss. 36.** f. 8	.....	.....	*				
undata, Hall, Pal. N. York, p. 165	.....	.....	*				
AVICULA ampliata, Phil. M. G. S. ii. p. 367	.....	.....	.....	.....	.....	*	
antiqua, Goldf.? Pet. p. 283	.....	.....	.....	.....	.....	*	
bullata, M'Coy, Sil. Fos. p. 23	.....	.....	.....	*			
Danbyi, M'Coy, **Foss. 59.** f. 2, 3	.....	.....	.....	.....	.....	*	
mira, Barr. MS.	.....	.....	.....	.....	.....	*	
panopæsformis, M'Coy, Sil. Fos. p. 22 (also posidoniæformis, M'Coy)	.....	.....	.....	.....	*		
PTERINEA asperula, M'Coy, **Foss. 59.** f. 4	.....	.....	.....	.....	*		
Boydii, Conr. Pal. Fos. p. 259	.....	.....	.....	.....	.....	*	
demissa, Conr. (var. of retroflexa, His.)	.....	.....	.....	*	*	*	
fimbriata, M'Coy, Sil. Fos. p. 21	.....	.....	.....	.....	*		
hians, M'Coy, Pal. Fos. p. 260	.....	.....	.....	.....	.....	*	
lineata, Goldf. Pet. G. t. 119. f. 6?	.....	.....	.....	.....	.....	*	
lineatula, d'Orb., **Pl. 23.** f. 16	.....	.....	.....	.....	*	*	
megaloba, M'Coy, Pal. Fos. p. 261	.....	.....	.....	.....	.....	*	
orbicularis, M'Coy, Sil. Fos. p. 21	.....	.....	.....	.....	*		
? planulata, Conr. M. G. S. ii. p. 368	.....	.....	.....	*	*	*	
pleuroptera, Conr. Pal. Fos. p. 261	.....	.....	*	.....	*	*	
rectangularis, Sow., **Pl. 34.** f. 4	.....	.....	.....	.....	.....	*	
retroflexa, Wahl., **Pl. 9.** f. 26; **23.** f. 17 (squamosa, M'Coy)	.....	.....	.....	*	*	*	
Sowerbyi, M'Coy, **Pl. 23.** f. 15	.....	.....	.....	.....	.....	*	
subfalcata, Conr. Pal. Fos. p. 263	.....	.....	.....	.....	*	*	
sublævis, M'Coy, Sil. Fos. p. 23	.....	.....	.....	*			
tenuistriata, M'Coy, **Foss. 59.** f. 5	.....	.....	*?	.....	*	*	
(Dimyaria.)							
ANODONTOPSIS angustifrons, M'Coy, Pal. Fos. p. 271	.....	.....	.....	.....	.....	*	
bulla, M'Coy, **Foss. 60.** f. 5	.....	.....	.....	*	.....	*	
lævis, Sow. sp., Pal. Fos. p. 271	.....	.....	.....	.....	.....	*	
perovalis, Salt. sp., Mem. G. S. ii. p. 363	.....	.....	.....	.....	.....	*	
quadratus, M'Coy, Pal. Fos. p. 272	.....	.....	.....	.....	.....	*	
securiformis, M'Coy, Pal. Fos. p. 272	.....	.....	.....	.....	.....	*	
ARCA ? primitiva, Phil. Mem. G. S. ii. p. 366	.....	.....	.....	.....	.....	*	
CARDIOLA fibrosa, Sow., **Pl. 23.** f. 11	.....	.....	.....	.....	*	*	
interrupta, Sow., **Pl. 23.** f. 12	.....	.....	*?	.....	*	*	
semirugata, Portl. sp., Geol. Rep. p. 430	.....	.....	*				
? striata, Sow., **Pl. 23.** f. 13	.....	.....	.....	.....	*	*	
CLEIDOPHORUS ovalis, M'Coy, Pal. Fos. p. 273	.....	.....	*	*?	*		
planulatus, Conr. Pal. Fos. p. 273	.....	.....	.....	.....	*		
CTENODONTA (**p. 213**), [Nucula, sp., Arca, sp., &c.] ambigua, Portl. sp., Geol. Rep. p. 430 (and Pectunculus Apjohni, Portl.)	.....	.....	*				
Anglica, d'Orb., **Pl. 23.** f. 10	.....	.....	.....	.....	.....	*	
deltoidea, Phil. Mem. G. S. ii. p. 366	.....	.....	.....	*			
dissimilis, Portl. sp., Geol. Rep. p. 428	.....	.....	*				

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
Ctenodonta Eastnori, Sow., **Pl. 10.** f. 9				*			
Edmondiiformis (Arca), M'Coy, Pal. Fos. p. 283			*				
lævis, Sow., **Pl. 7.** f. 3		*					
lingualis, Phil. M. G. S. ii. p. 367				*			
obliqua, Portl., **Foss. 36.** f. 6			*				
ovalis, Sow. Sil. Syst. p. 609					*	*	
poststriata, Emmons, Pal. N. Y. i. p. 151					*		
quadrata, M'Coy, Sil. Fos. p. 20			*				
radiata, Portl. sp., Geol. Rep. p. 430			*				
regularis, Portl. sp., Geol. Rep. p. 427			*				
rhomboidea, Phil. Mem. G. S. ii. p. 367				*			
scitula, M'Coy, Sil. Fos. p. 20			*				
semitruncata, Portl. Geol. Rep. p. 429			*				
subacuta, M'Coy, Sil. Fos. p. 19			*				
subæqualis, Sow., **Pl. 10.** f. 7, 8				*		*	
subcylindrica, M'Coy, Sil. Fos. p. 19				*			
transversa, Portl. Geol. Rep. p. 427 (A. subtruncata, id.)			*				
varicosa, Salt., **Foss. 36.** f. 4			*				
Cucullella Anglica, Salt., **Foss. 8.** f. 2		*				*	
antiqua, Sow., **Pl. 34.** f. 16			*?			*	
Cawdori, Sow., **Pl. 34.** f. 3						*	
coarctata, Phil. M. G. S. ii. pt. 1. p. 366						*	
ovata, Sow., **Pl. 34.** f. 17						*	
Dolabra ? elliptica, M'Coy, Pal. Fos. p. 269						*	
obtusa, M'Coy, Pal. Fos. p. 270						*	
Goniophora cymbæformis, Sow., **Pl. 23.** f. 2; **34.** f. 15						*	
sp.				*			
Grammysia cingulata, His., **Foss. 60.** f. 1					*	*	
extrasulcata, Salt. M. G. S. ii. pt. 1. pl. 361						*	
rotundata, M'Coy, Pal. Fos. p. 281						*	
triangulata, Salt., **Foss. 60.** f. 2						*	
Lyrodesma cuneata, Phil. Mem. G. S. ii. p. 366				*			
plana, M'Coy, **Foss. 36.** f. 5			*				
Megalomus, sp., **p. 214**			*				
Modiolopsis (Modiola) antiqua, Sow., **Pl. 23.** f. 14					*		
complanata, Sow., **Pl. 23.** f. 1						*	
expansa, Portl., **Foss. 36.** f. 2			*				
gradata, Salter (Nilssoni), **Foss. 60.** f. 8					*	*	
inflata, M'Coy, Pal. Fos. p. 266			*				
modiolaris, Conr., **Foss. 36.** f. 3			*				
Nerei, Portl. Geol. Rep. p. 424			*				
obliqua, Sow., **Pl. 7.** f. 2			*				
orbicularis, Sow., **Pl. 7.** f. 1			*	*			
perovalis, Salt. Mem. G. S. ii. pt. 1. p. 263						*	
platyphylla, Salt., **Foss. 60.** f. 7						*	
postlineata, M'Coy, **Foss. 36.** f. 1			*				
quadrata, Salt. Mem. G. S. ii. p. 363						*	
securiformis, Portl. Geol. Rep. p. 425			*				
Mytilus Chemungensis, Conr. ? M. G. S. ii. pt. 1. p. 365					*		
cinctus, Portl. Geol. Rep. p. 426			*				
exasperatus, Phil. Mem. G. S. ii. p. 364					*		
mytilimeris, Conr., **Foss. 60.** f. 6			*?	*	*		
unguiculatus, Salt. Mem. G. S. ii. p. 365			*		*		

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
ORTHONOTA (Sanguinolites, sp., M'Coy) amygdalina, Sow., **Pl. 23.** f. 6, var. f. 7						*	
angulifera, M'Coy, **Foss. 60.** f. 3						*	
globulosa, M'Coy, Pal. Fos. p. 278						*	
impressa, Sow., **Pl. 23.** f. 3						*	
nasuta, Conr., **Foss. 12.** f. 12			*				
prora, Salt., **Foss. 60.** f. 4 (semisulcata, M'Coy)						*	
rigida, Sow., **Pl. 23.** f. 8						*	
rotundata, Sow. (Mya, Sil. Syst.), **Pl. 23.** f. 5						*	
semisulcata, Sow. (Modiola), Sil. Syst. p. 617						*	
solenoides, Sow., **Pl. 23.** f. 9						*	
truncata, M'Coy, Pal. Fos. p. 279						*	
undata, Sow., **Pl. 23.** f. 4						*	
PLEURORHYNCHUS (Conocardium) æquicostatus, Phil., **Foss. 59.** f. 1					*		
dipterus, Salt., **Pl. 36.** f. 7			*				
pristis, Salt. Sil. Fos. Irel. p. 71				*			
GASTEROPODA.							
ACROCULIA (Capulus, Nerita, &c.) euomphaloides, M'Coy, Pal. Fos. p. 290						*	
Haliotis, Sow., **Pl. 24.** f. 9				*	*		
prototypa, Phil., **Pl. 24.** f. 8					*		
CHITON Grayanus, Kon. Bul. Ac. Roy. Brux. iii. f. 1					*		
(Helminthochiton) Griffithii, Salter, **Foss. 37.** f. 8				*			
Wrightianus, Kon. Bull. Ac. Roy. Brux. iii. f. 2					*		
CYCLONEMA (Turbo) concinna, M'Coy, Sil. Fos. p. 12			*				
corallii, Sow., **Pl. 24.** f. 1						*	
crebristria, M'Coy, Pal. Fos. p. 295			*				
octavia, d'Orb., **Pl. 24.** f. 4						*	
quadristriata, Phil. Mem. G.S. ii. p. 388				*			
rupestris, Eichw., **Foss. 37.** f. 4			*				
sulcifera, Eichw., Urw. Russl. t. 2. f. 14			*				
undifera, M'Coy, Pal. Fos. p. 306						*	
ventricosa, Hall, Pal. N. York, ii. p. 90				*			
EUOMPHALUS alatus, His., **Pl. 26.** f. 4					*	*	
carinatus, Sow., **Pl. 24.** f. 11						*	
centrifugus, Wahl. Pal. Fos. p. 297					*	*	
Corndensis, Sow., **Pl. 7.** f. 5		*					
discors, Sow., **Pl. 24.** f. 12					*		
funatus, Sow., **Pl. 26.** f. 3				*	*	*	
lautus, M'Coy, Sil. Fos. p. 14					*		
præmuntius, Phil. Mem. G. S. ii. p. 357				*			
rugosus, Sow., **Pl. 24.** f. 13					*		
sculptus, Sow., **Pl. 9.** f. 27; **26.** f. 2					*	*	
tenuistriatus, Sow. (see Bellerophon perturbatus).							
HOLOPEA concinna, M'Coy, **Foss. 37.** f. 5			*				
striatella, Sow., **Pl. 7.** f. 4 (Trochus constrictus, M'Coy)			*				
HOLOPELLA cancellata, Sow., **Foss. 14.** f. 8; **Pl. 10.** f. 14						*	

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
HOLOPELLA conica, Sow., **Pl. 34.** f. 10; **Pl. 35.** f. 26						*	
gracilior, M'Coy, Pal. Foss. p. 303					*		
gregaria, Sow., **Pl. 34.** f. 10 *a*					*	*	
intermedia, M'Coy, Pal. Foss. p. 304						*	
monilis, M'Coy, Pal. Foss. p. 304			*				
obsoleta, Sow., **Pl. 9.** f. 28; **10.** f. 14; **34.** f. 11				*		*	
plana, M'Coy, Sil. Foss. p. 12				*			
tenuicincta, M'Coy, Pal. Foss. p. 304				*			
LOXONEMA elegans, M'Coy, Pal. Foss. p. 302						*	
sinuosa, Sow., **Pl. 24.** f. 3						*	
MACROCHEILUS elongatus, Portl. (Polyphemus)			*			*	
fusiformis, Sow., **Pl. 10.** f. 13				*			
MURCHISONIA angulata, Sow., **Pl. 10.** f. 12				*			
angustata, Hall, Pal. N. York, t. 10. f. 2			*				
articulata, Sow. sp., **Pl. 24.** f. 2						*	
balteata, Phil. sp., Mem. G. S. ii. p. 358					*		
bicincta, M'Coy (not of Hall)			*				
cancellatula, M'Coy, Pal. Foss. p. 292			*	*			
cingulata, His. Pal. Foss. p. 293						*	
corallii, Sow., **Pl. 24.** f. 7						*	
gyrogonia, M'Coy, **Foss. 37.** f. 6			*				
inflata, M'Coy, sp., Sil. Foss. p. 15				*			
Lloydii, Sow., **Pl. 24.** f. 5					*	*	
obscura, Portl., **Foss. 37.** f. 3			*				
Prycese, Sow., **Pl. 10.** f. 11				*			
pulchra, M'Coy, Pal. Foss. p. 294			*	*			
simplex, M'Coy, Pal. Foss. p. 294			*	*			
subrotundata, Portl., **Foss. 37.** f. 7			*				
sulcata, M'Coy (Lloydii?), Sil. Foss. pl. 1. f. 20				*			
torquata, M'Coy, Pal. Foss. p. 294						*	
turrita, Portl. sp., Geol. Rep. p. 412			*				
NATICA parva, Sow., **Pl. 25.** f. 1						*	
OPHILETA compacta, Salt., **Foss. 38.** f. 4		*					
macromphala, M'Coy, Pal. Foss. p. 300			*				
PATELLA Saturni, Goldf., **Foss. 37.** f. 9			*				
PLATYSCHISMA helicites, Sow., **Foss. 25.** f. 9; **Pl. 34.** f. 12						*	*
Williamsi, Sow., **Pl. 34.** f. 14				*?		*	
PLEUROTOMARIA crenulata, M'Coy, Pal. Foss. p. 291						*	
fissicarina, Phil. Mem. G. S. ii. p. 357				*			
trochiformis, Portl. Geol. Rep. p. 413			*				
sp. (trochiformis, M'Coy), Sil. Foss. p. 16					*		
undata, Sow., **Pl. 24.** f. 6						*	
RAPHISTOMA æqualis (qualteriata, Salt.), **Foss. 37.** f. 2			*				
elliptica, Portl. Geol. Rep. p. 414			*				
lenticularis, Sow., **Pl. 10.** f. 10				*			
RIBEIRIA complanata (Redonia), Salt., **Foss. 8.** f. 3		*					
TROCHONEMA (Dec. Canadian Surv. 1) latifasciata, M'Coy, sp., Sil. Foss. p. 15			*				
lyrata, M'Coy, sp., Pal. Foss. p. 298			*				
tricincta, M'Coy, sp., Sil. Foss. p. 14				*			
triporcata, M'Coy, sp., Pal. Foss. p. 299			*		*		
trochleata, M'Coy, sp., Sil. Foss. p. 12				*			
TROCHUS? cælatulus, M'Coy, Pal. Foss. p. 296				*			

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
TROCHUS Moorei, M'Coy, Pal. Foss. p. 297				*			
? multitorquatus, M'Coy, Sil. Foss. p. 15				*			
TURBO ? cirrhosus, Sow., **Pl. 24.** f. 11					*		
tritorquatus, M'Coy, Sil. Foss. p. 12				*			
HETEROPODA.							
BELLEROPHON acutus, Sow., **Foss. 39.** f. 7; **Pl. 7.** f. 8			*	*?			
alatus, Portl. Geol. Rep. p. 471			*				
bilobatus, Sow., **Foss. 12.** f. 10; **Pl. 7.** f. 9		*	*	*?			
carinatus, Sow., **Pl. 34.** f. 8			*	*		*	
dilatatus, Sow., **Foss. 39.** f. 8; **Pl. 25.** f. 5, 6			*	*	*		
expansus, Sow., **Pl. 25.** f. 8; **34.** f. 20; **35.** f. 28						*	
Murchisoni, d'Orb., **Pl. 34.** f. 19 (B. striatus)						*	
nodosus, Salt., **Foss. 12.** f. 11			*				
obtectus, Phil. Mem. G. S. ii. p. 356						*	
perturbatus, Sow. sp., **Foss. 39.** f. 6; **Pl. 7.** f. 6, 7 (Euomphalus tenuistriatus, Sow; furcatus, M'Coy)		*					
subdecussatus, M'Coy, Pal. Foss. p. 311				*	*		
sulcatinus, Emmons, Pal. N. Y. i. p. 32			*				
Wenlockensis, Sow., **Pl. 25.** f. 7					*		
sp., Salt. Geol. Journ. x. p. 74				*			
PTEROPODA.							
CONULARIA elongata, Portl., **Foss. 39.** f. 3			*				
Sowerbyi, Defr., **Pl. 25.** f. 10			*	*	*	*	
subtilis, Salt. Pal. Foss. p. 288						*	
ECCULIOMPHALUS (Cyrtolites, Conr., in part) Bucklandi, Portl., **Foss. 39.** f. 5			*				
(Cyrtolites) lævis, Sow., **Pl. 25.** f. 9						*	
Scoticus, M'Coy, Pal. Foss. p. 301			*	*			
MACLUREA Logani, Salt., **Foss. 37.** f. 1, 1 *a*		*					
magna, M'Coy (Lesueur ?), Pal. Foss. p. 300		*					
Peachii, Salt., **Foss. 38.** f. 1, 2		*					
PTEROTHECA corrugata, Salt. Brit. Assoc. 1852, p. 61			*				
transversa, Portl., **Foss. 39.** f. 4			*				
sp.				*			
THECA anceps, Salt. Mem. G. S. ii. pt. 1. p. 355					*		
Forbesii, Sharpe, Geol. Journ. ii. p. 314					*	*	
reversa, Salt., **Foss. 10.** f. 21; **39.** f. 1		*					
simplex, Salt., **Foss. 8.** f. 5		*					
triangularis, Portl., **Foss. 39.** f. 2			*?				
vaginula, Salt., **Foss. 9.** f. 14		*					
CEPHALOPODA.							
ASCOCERAS Barrandii, Salt., **Foss. 62.**						*	
CYRTOCERAS approximatum, Sow. sp., **Pl. 11.** f. 4				*			
inæquiseptum, Portl., **Foss. 41.** f. 1 (Phragmoceras Brateri, Portl.)			*				
multicameratum, Hall, Pal. N. Y. p. 195		*?					
LITUITES anguiformis, Salt. Pal. Foss. App. p. viii.			*				
articulatus, Sow., **Pl. 31.** f. 6						*	

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
LITUITES Biddulphii, Sow., **Pl. 31.** f. 5					*		
cornu-arietis, Sow., **Foss. 41.** f. 2; **Pl. 7.** f. 10; **11.** f. 1, 2			*	*			
giganteus, Sow., **Pl. 36.** f. 1–3					*	*	
Hibernicus, Salt., **Foss. 41.** f. 3			*				
planorbiformis, Conr. Pal. N. York, t. 84			*				
tortuosus, Sow., **Pl. 33.** f. 4					*?	*	
undosus, Sow., **Pl. 11.** f. 3				*			
sp. (cornu-arietis, Portl.) G.R. pl. 28B. f. 7			*				
ORTHOCERAS angulatum, Wahl., **Pl. 28.** f. 4 (O. virgatum, Sil. Syst.)			*	*	*	*	
annulatum, Sow., **Pl. 26.** f. 1, 2			*	*	*		
arcuoliratum, Hall, Pal. N. York, p. 198			*				
attenuatum, Sow., **Pl. 26.** f. 3					*		
Avelinii, Salt., **Foss. 8.** f. 4		*					
baculiforme, Salt. Pal. Fos. App. p. vi						*	
Barrandii, Salt. G. J. vii. p. 177				*			
bilineatum, Hall, **Foss. 40.** f. 2 (O. subannulatum, calamiteum, tubicinella, Portl.)			*				
breviconicum, Portl. Geol. Rep. p. 373			*				
Brongniarti, Troost, **Foss. 40.** f. 4			*				
bullatum, Sow., **Pl. 29.** f. 1						*	
canaliculatum, Sow., **Pl. 28.** f. 3					*		
centrale, His.? Pal. Fos. p. 314			*				
coralliforme, M'Coy, Sil. Fos. p. 8				*			
dimidiatum, Sow., **Pl. 28.** f. 5						*	
distans, Sow., **Pl. 26.** f. 4						*	
encrinale, Salt., **Foss. 8.** f. 10		*					
elongato-cinctum, Portl. G. R. p. 372			*				
excentricum, Sow. Sil. Syst. p. 631					*		
filosum, Sow., **Foss. 61.** f. 1; **Pl. 27.** f. 1 fimbriatum (see annulatum).			*		*	*	
gregarium, Sow. Sil. Syst. p. 619						*	
ibex, Sow., **Pl. 29.** f. 3 (O. articulatum, Sow.)			*	*	*	*	
imbricatum, Wahl., **Pl. 29.** f. 7						*	
laqueatum, Hall, Pal. N. York, p. 206			*		*	*	
Ludense, Sow., **Foss. 61.** f. 1; **Pl. 28.** f. 1, 2						*	
Maclareni, Salt., **Foss. 24.** p. 126					*		
Marloense, Phil. Mem. G. S. ii. p. 353					*		
Mocktreense, Sow., **Pl. 29.** f. 2						*	
nummularium, Sow., **Pl. 26.** f. 5					*		
perannulatum, Portl. Geol. Rep. p. 367			*				
perelegans, Salt., **Pl. 29.** f. 5, 6 (Lituites articulatus, part, and L. ibex, Sow.)					*	*	
politum, M'Coy, Pal. Fos. p. 316			*				
Pomeroense, Portl. Geol. Rep. p. 370			*				
primævum, Forbes, **Foss. 61.** f. 4			*		*	*?	
subgregarium, M'Coy, Sil. Fos. p. 9				*			
subundulatum, Portl., **Foss. 61.** f. 3			*	*	*	*	
tenuiannulatum, M'Coy, Pal. Fos. p. 320						*	
tenuicinctum, Portl., **Foss. 40.** f. 3			*		*		
tenuistriatum, Münst., Beitr. 3. t. 19. f. 4.				*			
textile, Phil. Mem. G. S. ii. pt. 1. p. 353						*	
torquatum, Münst. Pal. Fos. App. p. vii						*	
tracheale, Sow., **Pl. 34.** f. 6 (O. perelegans, Salt.?)						*	

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	Lingula Flags.	Llandeilo Rocks.	Caradoc or Bala.	Llandovery Rocks.	Wenlock.	Ludlow.	Passage-beds.
ORTHOCERAS vagans, Salt., **Foss. 40.** f. 1			*				
vaginatum, Schlot., Geol. J. vii. p. 377			*				
ventricosum, Sharpe, Geol. J. ii. t. 13					*		
ONCOCERAS, sp., **Foss. 38.** f. 6		*					
PHRAGMOCERAS arcuatum, Sow., **Pl. 31.** f. 3						*	
compressum, Sow., **Pl. 31.** f. 4				*	*	*	
intermedium, M'Coy, **Pl. 30.** f. 4						*	
nautileum, Sow., **Pl. 31.** f. 1, 2					*	*	
pyriforme, Sow., **Pl. 30.** f. 1–3						*	
ventricosum, Sow., **Pl. 32**					*	*	
POTERIOCERAS approximatum, M'Coy, Sil. Fos. p. 10 (O. subfusiforme, O. subpyriforme, Portl.)			*				
TRETOCERAS bisiphonatum, Sow. sp., **Pl. 11.** f. 5				*			
? semipartitum, Sow., **Pl. 34.** f. 5						*	
FISHES.							
AUCHENASPIS Salteri, Egert., **Foss. 21.** f. 2							*
? ornatus (Cephalaspis), Egert., **Foss. 21.** f. 3							*
CEPHALASPIS Murchisoni, Egert., **Foss. 22.** f. 1							*
large sp., with tubercular surface							*
ONCHUS Murchisoni, Ag., **Pl. 34.** f. 1; **35.** f. 13, 14						*	*
tenuistriatus, Ag., **Pl. 35.** f. 15, 17						*	
sp., shagreen of (Thelodus, Ag.), **Pl. 35.** f. 18						*	
PLECTRODUS mirabilis, Ag., **Pl. 35.** f. 3–8						*	*?
pustuliferus, Ag., **Pl. 35.** f. 9–12						*	
PTERASPIS Banksii, **Foss. 67.** f. 2						*	*?
truncatus, **Foss. 67.** f. 1						*	
SPHAGODUS, Ag., **Pl. 35.** f. 1						*	

NOTE.—There are a few other fossils, mentioned and figured in this work, which are not enumerated in the foregoing Table, namely PALÆOPYGE Ramsayi (**Foss. 1.** f. 2), referred to the Trilobite family, and two forms of OLDHAMIA (O. antiqua, **Foss. 2**, and O. radiata), which is described in the text as being probably a zoophyte; some naturalists, however, doubt whether it has claims to more than a vegetable rank. These fossils, together with the Annelide markings, ARENICOLITES didymus, **Foss. 1.** f. 1, and A. sparsus, belong to the Cambrian rocks,—a lower zone of deposits (as explained in the text), in which scarcely any other fossil is known.

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B.—*Geology of the North of Scotland.*

The reader will have seen in the Frontispiece, and have found at pp. 11, 195, 217, *et seq.* of this work, that the oldest known rocks of the British Isles are composed of a highly crystalline, hornblendic gneiss with powerful granite veins, and that, in the North Highlands of Scotland, there is from that rock an ascending order in proceeding from N.W. to S.E., as rudely represented in the diagram, p. 199. But that diagram is not to be viewed as an absolute section: it simply represents the general succession of the great rock-masses of the three northern counties of Scotland. A visit to the north of Scotland since the greater part of this volume was printed has indeed completely confirmed these leading data;—a fundamental gneiss on the west coast, succeeded unconformably by mountain masses of purple and red conglomerate and grit (Cambrian), which in their turn are also unconformably overlaid by quartz rocks with a *subordinate* limestone charged with Lower Silurian fossils, of which the following is a fuller list than that which is given in the text.

In the lower quartz rock or quartzite:—a fan-shaped Fucoid, Annelide tubes, and Serpulites? Maccullochii, Salter. In the limestone:—several fossils identical with species occurring in Canada and the United States; such as Murchisonia angustata, Hall; M. bellicincta, ib.; Raphistoma labiata, Emmons?; Ophileta (Maclurea) compacta, Salter; Orthoceras undulatostriatum, Hall; O. arcuoliratum, Hall; O. moniliforme?, Hall; O. anellum, Hall; Orthis, like O. striatula of Emmons.

Besides the above species the following genera occur, all of which, as well as the preceding, occur in the Lower Silurian limestones of North America:—Pleurotomaria, sp.; Raphistoma, sp.; Ophileta (or Euomphalus), sp.; Euomphalus, sp.; Maclurea Peachii, Salter, and its operculum, in abundance; Cyrtoceras, two species, and a Lituites, the last apparently covered with sponge. A solitary coral is all that Mr. Salter has seen; but Mr. Lonsdale thought he found traces of others. Univalve shells, and particularly Murchisonia, are the prevalent forms.

These fossil-bearing beds are clearly and conformably covered by other crystalline rocks, whether consisting of quartzose mica-schists and flagstones, or younger strata having the characters of gneiss. One of the chief objects of my last visit to the Lower Silurian limestones of Durness and Assynt* was to be satisfied, by another appeal to nature, that there were quartz rocks (quartzites of Nicol) above as well as below the fossiliferous limestone. Such a succession, followed symmetrically upwards by mica-schists, flagstones, and a younger gneiss, was again seen on the eastern side of Loch Eribol, where that physical order was observed thirty-one years ago by Sedgwick and myself. I this year traced the same relations from Loch Eribol on the N.N.E. along intervening spots to the east end of Loch Stack and the western end of Loch More†, and again in tracts lying on and to the east and south-east of Loch Assynt,—a distance along the strike of not less than forty miles from N.N.E. to S.S.W. Another proof of the soundness of this general view is seen in the fact, that when the older or fundamental gneiss reappears amidst the overlying strata, as between Loch Durness and Loch Eribol, it throws off quartz rocks and limestones to the N.W., and

* Orthoceratites have now been detected by Mr. Peach and myself in Assynt.

† Where Col. James had previously noticed this order.

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places them in a basin,—a fact observed by Mr. Peach, but which escaped the notice of former observers. Now, if the fundamental gneiss had been thus protruded to the surface in other and more eastern places, similar reversals of the dip might have been looked for; but no such basin-shaped arrangements are seen for many miles to the east of the tracts where the order of succession has been described, and hence it follows that the older gneiss cannot be supposed to be reproduced as a surface-rock in the lofty mountains of the Central Highlands without calling in faults of stupendous dimensions. Again, if such faults existed, we should expect that in some portion of the central tracts of Sutherland, in which such old rocks are brought to day, they would be accompanied by those quartz rocks and limestones which appear in great force near the west coast of the same county; but this is never the case. In truth, the Lower Silurian rocks of the west coast are deeply buried, as we advance to the east and south, under micaceous and thin flaggy metamorphic strata which are very dissimilar to the old gneiss of the west.

It would, however, ill become any geologist to dogmatize respecting a vast region, many parts of which are most difficultly traversed and are yet unexamined, and therefore I guard myself by saying that there may be tracts, particularly in the north and north-eastern parts of Sutherland, near its confines with Caithness, where the older gneiss is again brought up to the surface along with those great granitic masses which appear in force towards the eastern side of Sutherland. At all events that view cannot be sustained if the traverse be made from Loch Assynt on the north-west to Bonar Bridge on the south-east. The granitic veins of the west coast seem, indeed, to be essentially different from the massive granites of the east. Those of the north-west are really subordinate, and confined, to a rock which underlies the oldest visible strata of conglomerate and sandstone of the British Isles, whilst those of the south-east penetrate and alter strata that are evidently nothing but mica-schists and quartzose flagstones, which, though essentially different from the old gneiss at certain distances from such granitic intrusions, have necessarily a considerable resemblance to them at such points of alteration and contact. Yet, that these mica-schists and flaggy beds really overlie all the inferior masses of older gneiss, Cambrian sandstones, and Lower Silurian quartzites and limestones, no one can doubt who proceeds from Assynt by Strath Oikel and Lairg to Bonar Bridge. He will then see that all the Lower Silurian rocks of the north-west and west are covered by a flag-like micaceous series of very different and uniform structure, the strata of which dip steadily to the E.S.E., particularly on the banks of the Oikel, until they are broken through by the younger granitic masses in question, and are at such points necessarily both altered and much dislocated.

Again, if some one should suggest that the quartz rock of the Scarabin Hills of the south-eastern part of Caithness may represent the old lower quartz rocks of the west coast, I would beg him to examine the structure and relations of the two, and he will abandon that idea. The quartz rocks of the west are manifestly altered sandstones or quartzites, which, whether they lie upon purple Cambrian conglomerate and sandstone, or on the ancient gneiss, are quite distinct from the pure quartz rock of the Scarabins, which is simply a mass of the grey overlying quartzose rocks, void of limestones, and metamorphosed by the powerful eruptions of granite, which, enveloping all such stratified rocks on the banks of the Langwell and Berridale Rivers, jut out on the coast in the bold promontory of the Ord of

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Caithness, where the passage of the granite into compact felspar rocks may be admirably studied.

But passing over the doubt as to whether the explorer who may work out in detail the whole of this northern succession may find some tracts towards the north-east in which the true old gneiss of the west coast has been brought to day, I dwell upon the plain broad fact, that the thin micaceous flagstones, often used as slates, and invariably splitting along the planes of the original deposit, which occur at various places in Ross-, Inverness-, Moray-, and Banff-shire on the east coast, can never be confounded with the great massive fundamental granitoid and hornblendic gneiss of the north-west coast, any more than similar overlying beds between Lochs Eribol and Tongue in the same tract.

However, therefore, certain details may hereafter be settled, this great feature of the reform of the classification in the older rocks of the N. of Scotland stands out as the most prominent geological advance which has been made for some years, and I rejoice that I have taken an active part in establishing it, and in showing that the hypothetical views I have for some time entertained have been borne out by a rigorous appeal to nature.

In speaking, however, of this reform in the classification of the rocks of the North Highlands, justice must be done to a most remarkable memoir by the late Mr. R. J. H. Cunningham, entitled "The Geognosy of Sutherlandshire," published in 1839 (Transactions of the Highland Society of Scotland, vol. xiii.); for, although this work was referred to in a note, p. 196 (in which the author's name is misspelt), I owe a distinct apology to his memory and reputation for having included him in the list of those geologists who, like myself (and, as I thought, all my contemporaries), had classed together the red sandstones of the west and east coasts. In fact, I was guided by the geological map of Mr. Cunningham, in which the sandstones of the east and of the west are represented *under one colour*. Hence I naturally inferred that he considered those rocks to be equivalent masses. On recently perusing his memoir, however, I find that he gives some good reasons for their separation, as depending on differences of structure and position; and, although he does not dwell upon the great features of superposition and posteriority which I have advanced, still he states, that, as the red sandstones of the east coast afford appearances distinct from those which are found in the conglomerate and sandstone of the quartz system, "he deemed it safer to describe the two groups individually than to run the hazard of confounding them." As this memoir must have been well known in Scotland, it seems surprising that no geologist of my country (I was then busily embarked in Russian and continental researches) should have endeavoured to settle such a question by a subsequent investigation, until, accompanied by Prof. Nicol, I went to Sutherland fourteen years later!

Again, Mr. Cunningham, who spent much time and laboured much more sedulously in Sutherland than any other geologist, not only clearly pointed out the intercalation of the Assynt and Durness limestones with quartz rocks, but also gave numerous examples of the superposition of a younger gneiss with micaceous and chloritic schists to the "quartz-rock system,"—a phenomenon, however, which Sedgwick and myself had observed many years before. Proclaiming his belief that this upper group was to be referred to the "Transition series," and adverting to the important fact of the existence of two systems of crystalline rocks in Sutherland, he thus wrote: "There is found a gneiss newer than a quartz rock,

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which [latter] has resulted from the breaking-up of a still older formation; and as organized fossils have [elsewhere] been discovered in the oldest-known mechanically formed strata, there is also some cause to believe that there are gneisses and mica-slates that have been elaborated after these were called into being." On the other hand, in his description of the oldest gneiss, which, like his precursor M°Culloch, he could not avoid seeing was overlaid by red sandstone and conglomerate, he still represented the whole upon his map under one colour; being, we may presume, unable to free himself from the prevalent mineralogical notion, that all crystalline stratified rocks containing mica, quartz, and felspar must be united in the Gneiss family. Though he failed to observe the striking unconformability between the lower red sandstone with conglomerate and the overlying quartz rocks, and, like M°Culloch, grouped erroneously these discordant masses in one system; still, considering the period of its publication, and our total ignorance at that time respecting the organic remains of the quartz rock and limestone zone, since discovered by Mr. Peach, the memoir and map of Cunningham are deserving of all praise. Those portions of his writings which relate to the association of granite and its veins with gneiss and other crystalline rocks are, indeed, well calculated to incite others to a renewed attention to that class of phenomena.

Before we quit the consideration of the rocks of Silurian age, let me add, that whilst I write, and since I left Scotland a few weeks ago, Professor Ramsay, Mr. Salter, and Mr. Geikie have made the discovery of the existence of Graptolites in the hard thin-bedded rocks of Siccar Point in Berwickshire. This fact determines the purple schists of that coast (which, from their mineral aspect, had been supposed to be of the Longmynd age) to be really Lower Silurian, and involves the necessity of a correction of the text p. 166, and of the end of the note p. 165,—the convoluted strata seen in the drawing of the cliffs near St. Abb's Head being really prolongations of the rocks of Siccar Point, and therefore of Silurian age.

Other reforms which have been effected, and of which the first printed detail appears in this volume, relate to the Old Red Sandstone properly so called, or those rocks of conglomerate, sandstone, schist, flagstone, and limestone, which I consider to be the full equivalents in time of the Devonian rocks of the S. of England and the Continent.

It has been shown, that the conglomerates and sandstones which in the North-eastern Highlands form the base of this series are compounded out of all the pre-existing rocks above described, whether gneiss, older grits, quartz rock, mica-schist, granite, &c., as ranging in ascending order from the west to the east coast (pp. 11, 179, 195, 277). To the numerous proofs of this admixture, Mr. C. Peach and myself made a very interesting addition in our last joint examination; for, notwithstanding the vast distance between the Silurian rock of Durness and Assynt and the red and yellow Old Red Sandstone of the east coast, we found in the latter near Dornoch, when in company with Mr. Dempster, of Skibo Castle, unquestionable fragments and pebbles of that finely laminated and peculiar grey chert, which so abounds in the Lower Silurian limestone of the west coast, and which is entirely unlike any other rock in the Northern Highlands. It is this great and thick lower zone of the Old Red of the Northern Highlands which, as before stated (pp. 280, 285), I consider to be the equivalent *in time* of those beds on the eastern and southern flanks of the Grampians (Arbroath,

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Dundee, Balruddery, &c.) which unquestionably constitute the base of the group, as demonstrated in England by their conformable union downward with the true Ludlow rocks or uppermost Silurian (see p. 149 *et seq.*). My belief, as first expressed to my geological associates at the Meeting of the Geological Society 3rd February, 1858 (and repeated at p. 282 *et seq.* in this volume), that the Caithness flagstones with their numerous ichthyolites constitute the central portion of the Old Red group, was everywhere sustained by my last researches accompanied by Mr. Peach, during which I received much valuable information from Mr. Robert Dick, of Thurso, respecting the detailed structure of Caithness, as also from Mr. John Miller, of the same place, both of whom contributed good paleontological data, all of which, including additional facts derived from a survey of the Orkney Islands, are about to be laid before the Geological Society. One of the points to which Mr. Dick directed my notice, was the presence of numerous powerful fractures and dislocations in the flagstones ranging over Caithness, and which to the superficial observer seem to lie simply in undulations. But to whatever extent these dislocations and upheavals have occurred (and they largely exist), they never can be accurately defined until a correct map of the county be executed; it being a melancholy fact, that, though very easily capable of examination, owing to the slight elevation of the greater part of the county, Caithness is probably the worst-mapped county in Scotland, or rather it possesses nothing which can be called a map.

Whilst the great features of the paleozoic succession in the N.E. of Scotland remain as they are described in the text, I made some important additions to our knowledge respecting the Old Red Sandstone during my personal inspection of this summer. Thus, when in company with Mr. Peach, I was reassured that the same flagstones as those of Caithness, and containing similar fishes and plants, reposed, near Kirkwall, the capital of the Orkneys, upon a lower red sandstone—the rock, in fact, out of which the beautiful Cathedral of that town is built,—and are surmounted in several of the islands by another sandstone, usually of a light and yellowish colour, but with some admixture of red, the most splendid natural view of which is at Hoy Head. There, the sandstone overlying the Caithness flags has a vertical thickness in the sea-cliff of 1100 feet! The entire succession of the group is thus seen in Pomona and Hoy.

It is in the superior sandstone, chiefly of a yellow colour, that the most important discoveries of fossils have been made during the last year in Morayshire. In the environs of Elgin, I made transverse sections, in company with the Rev. G. Gordon, of Birnie, from the edge of the crystalline rocks (there chiefly micaceous flagstone) to the maritime promontories of Burgh Head and Lossie Mouth, and, in spite of much drift, was convinced that the yellow sandstones in which the reptile Telerpeton Elginense was found are the uppermost part of the Old Red or Devonian series. In exploring the coast range from Burgh Head to Lossie Mouth, I observed that the strata had been raised up on an anticlinal, trending parallel to, and being, as I believe, a repetition of, the more inland ridge containing Telerpeton; and that, whilst the inland ridges are associated with hard, subcrystalline cornstones (limestone), first described by Professor Sedgwick and myself as similar to the Old Red cornstones of England, so the coast ridge at Lossie Mouth is flanked on the sea-shore by another band of cornstone, which in its turn is overlaid by flag-like, dark red sandstone, seen in reefs at low water. In this Morayshire series there is not a

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trace of a carboniferous plant, and the strata are so bound together by mineral characters, conformity, and transition (yellow beds occurring very low in the series), that they must all be grouped, according to our present evidences, with the Old Red or Devonian rocks.

And here I must cite, with the praise it deserves, an excellent memoir on this tract by my late lamented friend Dr. J. Malcolmson, which was read before the Geological Society in 1839. As an abstract only was published, owing to causes which are explained in Appendix S, p. 572, the Rev. G. Gordon, who has had access to a copy of the original, will shortly give the substance of it in the Edinburgh New Philosophical Journal.

Having examined the district in the years 1827 and 1840, the chief additional data which I gained during my last visit were owing to the discovery by Mr. Martin, of Elgin (who also first discovered fossil fishes to the S. of Elgin, and made the earliest geological map of the district), of a large bone in the very beds at Lossie Mouth which had formerly afforded the huge scales of the supposed fish, called Stagonolepis Robertsoni by Agassiz. On visiting these quarries with the Rev. G. Gordon, we were so fortunate as to discover other portions of this large animal; so that comparative anatomists have now determined that the Stagonolepis is a reptile. The existence of reptiles during the formation of this deposit might indeed have been established by the slabs which have for many years been found in the coast quarries near Cummingston*, between Burgh Head and Lossie Mouth, in which are the footprints, of different sizes, each footprint having the impression of several claws to it. One specimen, from Capt. Brickenden (who first described these footprints, as well as the position of the Telerpeton, Quart. Journ. Geol. Soc. vol. viii. p. 97), is in the Geological Society's Museum, and others have been sent to the Museum of Practical Geology, London; most of them having been contributed by Mr. Patrick Duff, of Elgin, the original possessor of the Stagonolepis and Telerpeton. The presence of a large reptile, as well as of the little Telerpeton (see p. 289), in this upper member of the Old Red Sandstone is thus established.

Large slabs with the impressions of footsteps were also recently collected by Mr. Beckles, who visited the Cummingston quarries after my inspection of them, and vigorously set to work to select instructive specimens, which I have not seen. Others were forwarded to me by the Rev. G. Gordon, who, having been long acquainted with the locality of the footsteps, and being assisted by various friends, has enriched the Jermyn Street Museum with illustrative specimens. The whole of this subject is about to be laid before the Geological Society, and on that occasion the part which Mr. Patrick Duff, Mr. Martin, Mr. Robertson, and other gentlemen of Morayshire have taken in these discoveries will be duly mentioned.

Seeing that the footprints occurred in the same ridge as the large bones, I had little doubt, when I first saw the latter, that they must also be reptilian; and afterwards Sir P. Egerton, who visited Elgin at my request to determine the point, confirmed this view, and entirely excluded them from the class of fishes. Again, as soon as I laid one of these bones before Professor Owen at the Leeds Meeting of the British Association, he pronounced it to be reptilian. Lastly, a large suite of these remains, including some from the Elgin Museum,

* The Masons Heugh quarry, where the footsteps abound, is on the property of Major Charles L. Cumming Bruce, M.P.

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others the property of Mr. Patrick Duff, and many additional large flagstones with footprints, procured by the Rev. G. Gordon, have been transmitted to the Museum of the Government School of Mines in Jermyn Street, where Professor Huxley is preparing a description of them. This naturalist is led, from what he has seen, to recognize the Stagonolepis as a reptile of a high order. (See Appendix Q.)

In Banffshire I explored the banks of the Spey, and visited the locality of Tynet Burn, where, through the kindness of Mr. Alexander Simpson, of Holl, I obtained a collection of fossil fishes of the genera Pterichthys, Coccosteus, Glyptolepis, Osteolepis, Cheiracanthus, Diplacanthus, &c. As these are forms also known in Caithness, it is interesting to observe, that the strata at Tynet lie far above the great mass of lowest Old Red Sandstone; they are, in fact, like the Gamrie ichthyolites, in the central zone of the group.

I had little time at my disposal for reviewing the great masses of sedimentary deposit lying along the eastern and southern faces of the crystalline rocks of the Grampians, which have been hitherto all classed as pertaining to the Old Red Sandstone, and I am not competent to describe their detailed relations.

On these points, however, which Mr. D. Page is working out with ability, I beg to offer the following suggestion. The true base in Shropshire and Herefordshire of the Old Red Sandstone, properly so called, is, I repeat, seen to be a red rock, containing Cephalaspis and Pteraspis (see pp. 153, 244 *et seq.*), and gradually passing down into the grey Ludlow rock; and in both of these contiguous and united strata, remains of large Pterygoti are found, but of different species in the two bands. Now, although the Arbroath paving-stone, and the grey rocks ranging to the north of Dundee, much resemble the uppermost Ludlow rock, they contain the Cephalaspis Lyellii, with another kindred species, and are therefore to be classed with the Devonian rocks, though they must, under every circumstance, be viewed as the very base of that natural group. It follows, therefore, that, if the great lower conglomerates on the flanks of the Grampians really underlie all those grey rocks with Pterygoti, Cephalaspides, and Parka decipiens, they can no longer be united as they have been with the Old Red or Devonian, but must represent some portion of the Silurian system*. In speaking of the lowest member of the Old Red Sandstone, as characterized by the Cephalaspis Lyellii, I repeat the expression of my conviction, that in the North-eastern Highlands and Caithness this lower zone is represented by the vast thickness of thin-bedded red sandstone and conglomerates, which had been already adverted to as lying beneath the Caithness flags. (See Abstracts of Proceedings of Geol. Soc., No. 18, 3rd February, 1858.)

Lastly, I visited Dura Den, in Fifeshire, in the company of Lord Kinnaird and the Rev. Dr. John Anderson, whose work on that beautiful tract is well known to geologists, and I now entertain no doubt whatever, that the yellow sandstones (with red layers) pertain truly to the Old Red group, that they are entirely subjacent to the equally yellow carboniferous sandstones with coal plants, and are of about the same age as the yellow sandstones of Elgin. A splendid specimen (now at Rossie Priory) of the genus Holoptychius, three feet long, was found on the occasion of this visit, on the property of Mrs.

* The diagrammatic section, p. 276, does not represent any lower conglomerates, though I have reason to believe that they exist.

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Dalgliesh; and, as a form very similar abounds also in the lower red portions of the deposit (at Clashbinnie), the age of the yellow sandstone is clearly substantiated. (See p. 574.)

In a communication made to the Geological Section of the British Association at Leeds, whilst the concluding chapters of this work were printing off, Mr. D. Page offered some "Further Contributions to the Paleontology of the Tilestones, or Siluro-Devonian strata of Scotland." He confirms my original view (see pp. 176 *et seq.*) that the Lanarkshire black schists are Upper Silurian, and has added many fossils, collected by Mr. Slimon, viz. Pterinea, Orthonota, Nucula, Avicula, Spirorbis, &c., together with new forms of Stylonurus, a crustacean allied to Eurypterus, all of which sustain the inference I formerly arrived at. The paving-stone or Forfarshire zone, which I consider to be higher in the series, and to be the true base of the Old Red or Devonian, has been enriched, through the labours of Mr. Page and Mr. Powrie, by the addition of two new crustaceans, Stylonurus and Kampecaris, and by the discovery of parts of the ichthyolite Cephalaspis Lyellii, and of another fine species, as well as many fish-spines, &c. The term "Tilestones," for which I have substituted "Passage-beds" in the Table, Appendix A, cannot therefore be made to include both the black schists of Lanarkshire (which are unquestionably Upper Silurian) and the Arbroath paving-stones, which must be regarded as the basement-beds of the Old Red.

Mr. D. Page informs me that the Cephalaspis has been found in Ayrshire.

C.—*Caithness Flagstones of the Old Red Sandstone.*

The Flagstones of Caithness, which were first described by me in the year 1827, under the name of "Bituminous schists" (Trans. Geol. Soc. 2 ser. vol. ii. p. 213), are in many places impregnated with bitumen, chiefly resulting from the vast quantity of fishes imbedded in them. Their most durable and best qualities as flagstones are derived from an admixture of this bitumen with finely laminated, siliceous, calcareous, and argillaceous particles, the whole forming a natural cement more impervious to moisture than any stone with which I am acquainted.

The following analyses of several specimens of Caithness flagstone and the accompanying bituminous shale, from the celebrated quarries of Castle Hill, belonging to my friend Mr. G. Traill, M.P., are indeed of high value, having been prepared under the superintendence of that distinguished chemist Dr. Hofmann.

These results completely sustain the opinion I was led to form upon the spot, that the peculiar tenacity and durability of these flagstones is due to the manner in which the silica and alumina are cemented together by certain proportions of calcareous and bituminous (organic) matter.

Mineral analysed.	Silica and Silicates, insoluble in HCl.	Oxide of Iron and Alumina.	Carbonate of Lime.	Organic matter.	Water, loss at 100° C.	Salts of Magnesia, the Alkalies &c.	Total.
No. 16. Top flag .	68·40	10·21	10·93	3·88	0·42	6·16	100·00
No. 7. Middle flag	69·45	11·50	10·66	5·79	0·40	2·20	100·00
Bituminous Shale .	69·96	8·15	7·72	10·73	0·53	2·91	100·00
No. 1. Bottom flag	61·39	4·87	21·91	3·40	0·20	8·23	100·00

In analysing a portion of the bituminous schists from the property of the

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Earl of Caithness (near Barrogill Castle), Dr. Hofmann reported to me as follows:—"When submitted to the action of heat, this substance evolves a considerable amount of gas, and likewise of oily matter containing a certain proportion of ammonia. The residue which remains behind is a greyish mass, consisting essentially of silicate of alumina (clay) mixed with a certain quantity of sesquioxide of iron and of sulphate of lime. A very minute proportion of phosphoric acid was likewise found to be present. The loss which the mineral undergoes on heating was found in two consecutive experiments to be 30·21 and 30·02; so that the mineral may be said to contain in round numbers—

Fixed matter (mineral)	70
Volatile matter (organic)	30
	100

"In determining the amount of gas furnished by the distillation of the mineral, a portion of it was heated in an iron tube, in order to imitate, as nearly as possible, the circumstances of an operation on a large scale. In two consecutive experiments which were performed in this manner, the following results were obtained:—

	Cub. centim.
I. 100 grammes furnished	7690
II. „ „ „	7430
Mean	7560

"Assuming 100 grammes of the mineral to yield, on an average, 7500 cubic centimetres of gas, a ton of the material would furnish 2690 cubic feet. The ordinary varieties of coal used in gas-making yield from 8000 to 10,000 cubic feet of gas per ton. The gas obtained from the mineral is very luminous; it is nearly entirely free from sulphur, and it is on this account very readily purified. The residue left in the retort after the expulsion of the gas retains but a small amount of carbon, viz. 8·5 per cent.; this residue has, therefore, but little value as coke.

"The mineral in question is in no way related to ozokerite, as has been suggested. From that substance it may be at once distinguished by its infusibility (ozokerite fuses at 80° C.=176° Fahr.), and by its entire insolubility in alcohol and ether, in which solvents ozokerite dissolves, although with difficulty."

D.—*Fossils of the Cambrian Rocks in Ireland*, pp. 26–28.

Dr. R. Kinahan has lately described the organic contents of the Cambrian rocks of Bray Head, in which he finds abundant traces of large and small annelide burrows, to one of which, belonging to a tentaculated worm, he applies the name Histioderma Hibernicum. He considers the Oldhamia to be truly a Sertularian polype, and thinks he has discovered the reproductive vesicles; and he describes one new species, the O. discreta, Kinahan, in addition to the well-known forms O. radiata and O. antiqua. (Transactions of the Royal Irish Academy, vol. xxiii. p. 547).

E.—*Primordial Zone in the Malvern Hills.*

It is stated in p. 104, that no remains, except fucoids, had yet been found in the Hollybush sandstone, or lowest visible stratified rock of the Malvern Hills.

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Dr. Grindrod, of Malvern, has however detected abundant traces of tubes referable to those of sea-worms, and one of which is a known Silurian genus, Trachyderma. The species has been provisionally named T. antiquissima, Salter, MS.

Additional reasons now exist for regarding, as I have done, p. 46, the Olenus shales of Malvern as belonging to the primordial zone, since the peculiar form Dictyonema sociale (p. 47) has been found in Keysend Hill by the Rev. W. S. Symonds.

The species appears, if not identical, at least very closely allied to the Phyllograpsus (Gorgonia) flabelliformis of Norway and Sweden. It appears, however, that both the names (Graptopora and Phyllograpsus) must give way to the previously published Dictyonema of James Hall, and the name of the species must therefore be corrected to Dictyonema sociale. It is the oldest known form of Bryozoon in Britain. In N. Europe a few graptolites occur with it.

From America we also receive new proofs continually of the persistency of this lower zone. Prof. W. Rogers has photographed a large Paradoxides found ten miles S. of Boston, thus probably giving us a locality for the long-known P. Harlani of Green. Recently a still larger and very broad species of the genus has been sent to the Museum of the Bristol Institution from the neighbourhood of St. John's, Newfoundland. Lastly, in Georgia, a specimen of sandstone has been found containing a species of Conocephalus. Neither this genus nor Paradoxides has been found out of the primordial zone (Lowest Silurian).

F.—*Conodonts of Pander.*

When these microscopic bodies were spoken of in the text, p. 374 *et seq.*, I slightly erred in stating that they were found below, or in the Ungulite grit of the Baltic provinces of Russia. Their exact position is in a thin bed of green sand above the courses of Ungulite grit and bituminous schist, and immediately beneath the chloritic or green-grained limestone which forms the base of the great Lower Silurian limestone (Pleta) of that region. Professor Huxley not having yet decided upon the true natural-history character of these little things, I have again had recourse to the microscopist. Professor Quekett, who, together with Dr. Carpenter, had formerly rejected them from the class of fishes, has renewed his examination, and is more than ever convinced that these minute spinous bodies cannot be the teeth of fishes. "However much," he says, "their external form may resemble a tooth, I have never been able in a single instance to detect in them the least trace of dental structure. I should rather be induced to consider them to be the cuticular spines of some animal. In their general shape they most nearly resemble the little denticles investing the tongue of many mollusca."

Just as this Appendix was going to press, I fortunately received the following communication from Professor Owen, which seems, indeed, to demonstrate that these organisms cannot have belonged to the Vertebrata:—

"*On the Lower Silurian organisms called 'Conodonts' by Dr. C. H. Pander**.—Minute, glistening, slender, conical bodies, hollow at the base, pointed at the end, more or less bent, with sharp opposite margins, might well be lingual teeth of Gasteropods, acetabular hooklets of Cephalopods, or teeth of Cartilaginous Fishes.

* "Monographie der Fossilen Fische (Unter-Silurische Fische, Conodonten)," 4to, 1856.

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"Against the latter determination is the minute size of the bodies called 'Conodonts' by Dr. C. H. Pander. Their basal cavity doubtless contained a formative pulp, but the proof that the product of such pulp was 'dentine' is wanting: the observed structure of the hooklet presents concentric conical lamellæ of a dense structureless substance containing minute nuclei or cells.

"In some specimens the base is abruptly produced and divided from the body of the hooklet by a constriction,—a form unknown to me in the teeth of any Fishes, but presented by certain lingual teeth of Gasteropods, *e. g.* the lateral teeth of Sparella. In other Conodonts the elongated base is denticulate or serrate, as in the lateral teeth of Buccinum and Chrysodomus. It is improbable, however, that they belong to any conchiferous toothed mollusk, the shells of such being wanting in the deposit where the Conodonts are most abundant.

"The more minute hooklets have a yellowish transparent horny appearance; the larger, perhaps older ones, present a harder whitish appearance. Their analysis by Pander yielded 'carbonate of lime,'—carbonic acid being evolved by application of dilute nitric acid, and oxalic acid producing an obvious precipitate.

"The detached condition of the hooklets and the integrity of the thin border of the basal pulp-cavity indicate that they have not been broken away from any of those kinds of attachment to a bone which the minute villiform teeth of osseous fishes would show signs of. The Conodonts have been supported upon a soft substance, such as the skin of a mollusk or worm, the mucous membrane of a mouth, or throat, or proboscis: but, to select the teeth of Cyclostomous or Plagiostomous fishes as the exclusive illustration of the above condition, is to take a partial and limited view of the subject.

"In comparing the Conodonts with the teeth of fishes, they present, as Dr. Pander recognizes, the closest resemblance, in that class, with the conical, pointed, horny teeth of Myxinoids and Lampreys: and the absence of any other hard part in the strata containing the Conodonts tallies with the condition of the Cyclostomatous skeleton; but not more than it does with the like soft condition of annelidous worms and naked mollusks. But the teeth of all known Cyclostomes are less varied in form than in the Conodonts. Certain lingual plates of Myxinoids are serrate, but not with a main denticle of much greater length, such as shown in the form of Conodont called Machairodus by Pander. Most Cyclostomous teeth are simple, thick cones, with a subcircular base: and every known tooth of a Cyclostomous fish is much larger than any of the forms of Conodont, which rarely equal half a line in length. This minuteness of size, with the peculiarities of form, inclines me strongly to refer the Conodonts to some soft invertebrate genus. Certain parts of small Crustacea, *e. g.* the pygidium or tail of some minute Entomostraca, resemble in shape the more simple Conodonts: but when we perceive that these bodies occur in thousands, detached, with entire bases, and that any part of the carapace or shell of an entomostracean or other crustacean has been rarely detected in the Conodont beds, it is highly improbable that they can have belonged to an organism protected by a substance as susceptible of preservation as their own substance. Much more likely is it that the body to which the minute hooklets were attached was as soluble and perishable as the soft pulp upon which the Conodont was sheathed. I find no form of spine, denticle, or hooklet in any Echinoderm, and especially in any soft-bodied one, to match the Conodonts, and conclude that they have

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most analogy with the spines, or hooklets, or denticles of naked Mollusks and Annelides.

"The formal publication of these minute ambiguous bodies from the oldest fossiliferous rocks as evidences of fishes is much to be deprecated."—RICHARD OWEN, *British Museum, Nov.* 18, 1858.

In confirming the view that the presence of phosphate of lime in these "Conodonts" is no indication of a bony character, Dr. Percy has further discovered that this substance occurs in the living whelk,—an interesting addition to the facts mentioned in the note at pp. 375, 376.

G.—*No Vertebrata in the Silurian Rocks of France.*

At the meeting of the Institute of France on the 19th of July last, and long after the chapter on France had been printed in this volume, M. Marie Rouault announced the discovery of vertebrated animals in the Silurian basin of the south-west of France (Comptes Rendus, vol. xlvii. p. 99), and stated that the two ichthyodorulites which he described, but did not figure (Machærium Archiaci and M. Larteti), came from the *Terrain Devonien* of the west of France. Subsequently M. de Verneuil, desirous of ascertaining the real nature of the rock in which the supposed ichthyodorulites were said to have been found, visited the district of St. Léonhard, in the northern part of the Department of La Sarthe, and ascertained, that the zone of rock whence the fossils of M. Rouault had come, was laden with characteristic trilobites of Llandeilo age, and reposed on an older band, of siliceous character, charged with Linguleæ, and representing the primordial Silurian fauna of Barrande, or the Lingula beds of Wales. At the same time, M. de Verneuil and M. Triger could detect no remains of ichthyodorulites in these rocks, but only elongated and somewhat incurvated bodies similar to those procured from the Director of the slate quarries by MM. Deville and Delesse, who gave them to M. Rouault,—that gentleman not having himself visited the locality.

Having ascertained these facts, I necessarily became anxious to inspect the remains which M. de Verneuil had collected from true Lower Silurian rocks, and which the Director of the slate quarries had called "Eels!" Wholly discrediting their belonging to vertebrata, and expressing to me the suggestion that they might prove to be flattened reeds, or some such bodies, M. de Verneuil sent these fossils to me for examination.

The largest of them (which was said by the Director of the quarries to be a finer specimen than any of the bodies given to MM. Deville and Delesse) is about 15 inches long, and has the shape of the blade of a somewhat incurvated dagger. Neither this form, nor any of the associated flattened or subcylindrical bodies which accompany it, have, in the opinion of Professor Huxley, Mr. Salter, Mr. Rupert Jones, and the other paleontologists to whom they have been submitted, the slightest trace *of any animal structure whatever*. They appear to be simply pyritous concretions around some soft elongated body—possibly a fucoid.

Thus vanish these Machæria from the class of fishes, like the supposed fish-defences of the Lower Silurian rocks of other countries, which have turned out on examination to be crustaceans, zoophytes, the tubes of annelides, or even sea-weeds!

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H.—*Fucoids and Annelide Burrows in the Lower Silurian Rocks of France.*

The well-known fossil impressions of the Vaux d'Aubin in Normandy, known to the natives as the "Pas de Bœuf," and which have been fully described by M. Deslongchamps (Mém. Soc. Linn. de Normandie, 1855), do not indicate the former presence of any large vertebrated animal. They are in all probability the impressions of sea-weeds (Cruziana?). Similar and equally large forms have been found by Logan in Canada, in the calciferous sand-rock, and had been previously described as the Fucoides biloba by Vanuxem (see his Geol. Rep. p. 79; Rusophycus bilobus, Hall, Palæont. N. Y. vol. ii. pl. 9), a fossil of the Clinton group. Mr. Salter, in a short note printed in the Bull. Soc. Géol. Fr. vol. xiii. p. 568, has again directed attention to these imprints; and he also refers the smaller double imprints on the same stone, called "Bouts de la canne de la calotte rouge," to the exit and entrance burrows of shore worms (Arenicolites).

It is at least worthy of remark, that in our own country, "foals' feet," as they are called, are a common form of impression in some sandstones—the Forfar pavement-beds of the Old Red Sandstone for instance. In that case they are, however, probably due, as Mr. Salter thinks, to tidal operations only.

I.—*Silurian Rocks of the Baltic Russian Provinces and Gothland.*

The work published by M. Fr. Schmidt, "Die Silurische Formation von Esthland, Nord-Livland, und Oesel," Dorpat, 1858, and of which I had only received a MS. abstract from Count Keyserling, has now reached me, and completely sustains the views I have put forth, pp. 377 *et seq.* Little justice, however, is done to M. Schmidt's valuable details in this volume, and the reader, who does not consult the original, is referred to my memoir in the Quarterly Journal of the Geological Society, vol. xiv. p. 43, "The Silurian Rocks and Fossils of Norway and the Baltic Provinces of Russia."

By a letter recently received from M. Schmidt, I further learn, that, in his examination of Gothland, he has ascertained that the sketch which I gave in 1847, respecting the British equivalents of that exclusively Upper Silurian Island, is correct. I then showed, that in proceeding from the Wenlock Shale and Limestone on the north, M. de Verneuil and myself reached younger strata on the south, the highest of which represented the Upper Ludlow Rock. This view, which had been opposed by Helmersen, is supported by Schmidt, who, among other arguments, shows that the strata at the south end of Gothland contain the same species of Eurypterus (E. remipes) as the uppermost beds of the opposite Russian isle of Oesel, which contain numerous unquestionable Ludlow fossils. A detailed history of the Eurypterus remipes will shortly be published by Dr. Mierzkowski, who, as well as M. Schmidt, believes that the Limulus is its nearest living congener.

In the expectation of publishing, with Dr. Schrenck, a description with figures of all the known Silurian fossils of the Russian Baltic provinces, M. Schmidt gives a detailed list of them, with references to the works of different authors. Among about 425 species enumerated, the Corals, Graptolites, &c., amount to nearly 80 species; the Crinoidea, Cystideæ, &c., to 13; the Cornulites, Tentaculites, and other Annelides to 5; the Bryozoa to 16; the Brachiopods to

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nearly 100; the Acephala, Pteropoda, Heteropoda, and Gasteropoda to 69; the Cephalopoda to 39; the Crustaceans, including Beyrichia, &c., to 67; and the Fishes (all of which, as in England, are in the uppermost Silurian zone) to 40. Towards the base of the Lower Silurian there are two Conodonts. Many of the species are identical with British forms.

K.—*Igneous Rocks of the Silurian Region of Britain compared with their German equivalents.*

In various parts of this volume, but particularly in the fourth chapter, the rocks of igneous origin, whether contemporaneous with or posterior to the strata with which they are associated, are mentioned in terms of which German geologists must wish to know the exact import. My illustrious friend Baron Humboldt, having requested me to send to him a few small specimens of the characteristic Silurian types of this class of rocks, has spoken of them in his fourth volume of 'Cosmos,' and has obligingly transmitted to me the following description of them as furnished by his eminent associate, M. Gustaf Rose:—

"In accordance with your wish, I send you herewith some remarks on the rock-specimens forwarded by Sir R. Murchison. The rock-specimens termed 'greenstone,' from Pembroke, Caernarvonshire, and Anglesea, are different varieties of hypersthenite and gabbro, such as occur near Neurode in Silesia, or at the Baste in the Harz—compounds of hypersthene or diallage with labradorite, which last has become snow-white or greenish white, and then is in the incipient state of change to serpentine; the hypersthene and diallage are also partly changed into uralite. The 'Felspar-porphyry,' from Caernarvonshire, is a syenite-porphyry with imbedded crystals of felspar and mica: oligoclase and hornblende also occur occasionally in addition. This rock is connected, as to its character, with the 'syenite' of Caernarvonshire: the 'syenite' of Merionethshire, on the other hand, contains much quartz, and has a more granitic character. The 'hornblende-porphyry' is a diorite very similar to the so-called 'Tiger-ore' of Schemnitz, but where the imbedded balls of hornblende are much larger; it is more like the diorite of Raschewsk in the Ural.

"The 'ash' of Snowdon and of Bala and the 'felspathic lava' of Snowdon are varieties of the green slate: in that of Snowdon are concretions resembling those of the so-called 'fruit-slate' (*Frucht-schiefer*) of Saxony; in that of Bala balls of hornstone occur, quite similar to the so-called felspathic lava of Snowdon, which perhaps is only a more quartzose portion of the green slate. The 'felspathic trap' of Snowdon is quartzose schist: the hollows in it, partially filled with iron-ore, are derived from decomposed included minerals, the nature of which is no longer to be ascertained. The 'felspathic ash' of Bala contains in its mass (or paste), which may be scratched with a knife, very small white crystals of felspar: it appears to be only a variety of the ordinary porphyry; but we ought to be able to see more of the rock, and to be acquainted with its geological conditions, in order to form a decided opinion on it. The 'felspathic ash' of Bishop's Castle is perhaps something similar, only more decomposed."

For my own part, adhering to the nomenclature used by my Geological associates of the Survey, I am of opinion that the names of felspathic ash, felspathic trap or lava, &c., really express the true nature of the conditions under

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which these rocks were formed. If the eminent mineralogist M. Gustaf Rose were to explore our Welsh mountains, he might probably adopt our views.

L.—*Australia.*

Owing to the kind permission of Lord Stanley and Sir E. Bulwer Lytton (H. M. Secretaries for the Colonies), I have been enabled to inspect the geological reports, maps, and sections of Victoria prepared by my friend Mr. Selwyn, and I take this opportunity of recording my sense of the high value of those documents. This able surveyor has already drawn the line of demarcation between the Lower and Upper Silurian rocks. Thus, all the rocks to the west of a line extending from Williams Town northwards to Lancefield are *Lower Silurian*,—Lingulæ and various forms of double Graptolites being, he says, the characteristic fossils. All the rocks of Silurian age to the east of the same line belong to the upper division. The rocks around Geelong are carboniferous* (oolitic?), similar to those on the E. side of Western Port, as well as several outliers. They have afforded no animal remains; the plants Phyllotheca and Glossopteris Browniana being characteristic fossils. These carbonaceous rocks rest unconformably on the Silurian, and are themselves unconformably overlaid by the tertiary deposits which Mr. Selwyn considers to be of eocene, miocene, and more recent age. All these formations, including the "gold drifts" of tertiary ages, as well as the eruptive rocks, whether granite, porphyry, or basalt, are coloured; their outlines being determined, and their relations shown, in a series of beautifully coloured transverse sections. It gives me, indeed, great pleasure to reflect, that the geologist who is so ably executing the important task confided to him, is a scion of the Geological Survey of the British Isles, who greatly distinguished himself in elaborating the difficult relations of the different members of the Silurian and associated igneous rocks in N. Wales.

The opinions of such a man on the gold veins and detritus of a region which he has sedulously explored during five years have had great weight with me, and have induced me to modify an opinion expressed in the first edition of this work. But, whilst gold-mining downwards to *small depths* in the solid veinstones of Victoria may for some years be a profitable business, it by no means follows that adequate profit is there to be maintained at great depths. The continuous working of deep mines (the law of the downward impoverishment of the ore being universally admitted) must depend upon the cost of extraction. Thus, in Transylvania and Hungary, where the gold was formerly visible near the surface, the lower portions of the same veinstones now worked afford a very minute quantity only of gold, which (according to Warington Smyth) would not be worth extraction but for the agency of powerful crushing-mills and the very low wages of the miners. (See the *caveat*, 'Siluria,' 1st edit. p. 436.)

M.—*Pteraspis and Pterygotus* (pp. 265, 267, 285).

The fish-fragments figured p. 267, as well as those given in Pl. 36 under the

* The progress of research has lately led to a clearer appreciation of the relative age of the various paleozoic rocks of New South Wales. There appears to be a true carboniferous series (beneath the secondary coal) overlying a Devonian group. The latter contains the well-known large Spirifers and bivalves.

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name Pteraspis, require a note of explanation as to the name. They received that name from Dr. Kner (see Haidinger's Abhandl. vol. i.) in 1847, who referred them to Cephalopoda. They have since been regarded by some as Crustacea, though Agassiz placed them among fishes of the genus Cephalaspis.

In a memoir recently read before the Geological Society (Quart. Journ. vol. xiv. p. 267), Professor Huxley has definitely included them in the class of fishes. I may here observe that my friends the Rev. W. Symonds and the Rev. F. Dyson, knowing the position in which these fishes ought to occur, have discovered them in their own Malvern district, and have detected all the principal species in the lower cornstones of the Old Red Sandstone at Cradley.

Note on Pterygotus gigas, p. 265.—I have scarcely referred sufficiently in the text to the labours of Mr. R. Banks with respect to the large *Pterygotus gigas* of Kington. That gentleman had been long collecting materials for the illustration of the species, and had been fortunate enough to discover a great number of parts, which he succinctly described in the Quart. Geol. Journ. for 1855, p. 97. On the publication, however, of the more complete specimens from Lanarkshire, he, with great liberality, made over his materials and drawings for description in a forthcoming Decade of the Geological Survey.

The Pterygotus so abundant at Ludlow and Kidderminster in the "Passage-beds" is the P. Ludensis; it has the greatest analogy with the Scotch fossil, P. Anglicus, which occurs at the very base of the Old Red Sandstone of Scotland. P. problematicus, on the contrary, which commences in the Upper Ludlow rock, appears to range quite into the Cornstone group, having been found lately by Dr. John Harley, of King's College, in the cornstones of Hopton Gate, Ludlow. This is the highest range of the genus known, and corresponds with the great extent to which the supposed egg-packets of this crustacean (Parka decipiens) are found in the Old Red Sandstone of Forfarshire. Tealing, near Dundee, is a new and rich locality of the Pterygotus.

N.—*Origin of Coal.*

The origin of coal, or rather the mode in which masses of vegetable matter have been successively entombed and converted into coal, has been discussed in the previous pages. I have there endeavoured to explain the prevalent hypotheses as to the terrestrial, freshwater, or drifted origin of coal, by assuming that in certain tracts one or other of these modes of accumulation may have occurred. (See pp. 312, 314, 316, 322, &c.)

Without abandoning the idea that coal must in certain places have been the result of drift agency, or the transport of vegetable matter into marine estuaries, and that in other cases it must have been formed under purely terrestrial and freshwater conditions, I may state, that an opinion has been gradually gaining ground among geologists and naturalists, that by far the greater part of the coal is the result of littoral growths (in sea-water or in maritime swamps) of succulent vegetables suited to these conditions, and that the occurrence of marine spoils among and over the beds of coal has been the normal condition of many coal-basins. It is certainly more likely that there should have been a gradual subsidence (with periodical pauses) in a mass of coal strata 12,000 feet thick, as in South Wales, than that there should have been repeated oscillations of the land—descending to receive marine productions, and raised again to

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sustain the growth of terrestrial plants. If the plants were capable of growing on the sea-margin (like mangroves in the West Indies), and if the water was very shallow, running into muddy lagoons, and full of sand-bars near the low swampy shores (a condition quite in accordance with what is represented in the vignette, p. 305), we should not need to invoke such repeated changes of level, but simple subsidence with occasional pauses. In confirmation of this view we have the fact, that, with the exception of the so-called Unio-bands, we have very little evidence of freshwater conditions at all; while the abundance of Serpula (Spirorbis) carbonaria, the occasional bands of Goniatites and Aviculæ even in the true coal-shales, and the frequent occurrence of marine shells and shark-like fish, point to a condition of things much more like that of the mangrove swamps above alluded to. It is further remarkable, that in existing lagoons a species of Unio is found, nearer in character (says the late Prof. E. Forbes) to the coal Unios than any true freshwater form.

An instance of the growth of geological theory based on observation and carried on by careful induction may be illustrated by the history of our views of the nature of coal-fields, the origin of which I endeavoured to elucidate in the 'Silurian System' by aid of an outline-map of an ideal portion of the coast of the Carboniferous Sea (p. 152), where freshwater and estuarine accumulations were supposed to be associated with coal, on the one hand, whilst further drifted vegetable matter was washed out to sea, on the other. Such an ideal coast-line has given place of late years to Mr. Austen's admirably worked-out geography of the North-west European Coal-area, traced with careful and indeed laborious exactitude on geological data (Geol. Journ. vol. xiii. p. 38, pl. 1); and now we have the still later researches of Mr. H. C. Sorby, directed from another point of view, but equally well indicating, by the evidences of former shoals and currents, the trend and character of the coal-bearing sea-margin.

Mr. Sorby, to whom we are indebted for so many good observations in physical geology, has arrived, by independent researches, at the conclusion, that the seas of the Coal period (in the North of England) were enclosed and shallow, with no very fixed or determinate lines of drift or current. In some valuable notes with which he has favoured me*, he shows, that during the deposition of the slate rocks of Westmoreland and the Lake district, in the Lower Silurian time, the currents came chiefly from the east, and in the Upper Silurian period from the N.N.W. These facts, when further developed, will throw great light on the physical geography of early times. He further indicates, that during the period of the Carboniferous limestone and Millstone grit, the sea was open to the west.

But these regular currents cease to be conspicuous when we rise into the Coal-measures in the same districts, the general current having then become almost extinct, and a confused set of tidal and wind drifts having supervened, which indicate a very considerable change in the physical geography of the region. These changes point, first, to a diminution of the current-flow in the period of the Millstone grit, then to a far more limited extension of the water during the Coal period, ending in a fresh set of currents during the Permian era among elongated shoals. How far these facts are in unison with the wide extent

* See also his papers on this subject in the Edinb. New Phil. Journ. vol. iii. p. 112, iv. p. 317, v. p. 275, vii. p. 226.

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and uniform character of the Coal-flora is a subject for future inquiry. We are, perhaps, warranted in believing, that a theory of the formation of coal, which should embrace as its chief element a widely extended series of shallow and partially enclosed seas fringed with swampy forests of water-loving plants, and subject to frequent subsidence, is perhaps most in harmony with observed phenomena.

O.—*Permian Fossil Plants.*

Just as this work is about to be issued to the public, I have received the instructive memoir of Dr. H. B. Geinitz on the plants of the Rothliegendes and Zechstein of Saxony (which deposits he has included, like myself, in the Permian group)—"Die Leitpflanzen des Rothliegenden und des Zechsteingebirges oder der Permischen Formation in Sachsen." Separating the Permian flora of the Roth- and Weiss-liegendes (as Gutbier and Göppert have done) from that of the Coal period, and enumerating many peculiar species, he specially illustrates in two plates the genera Palæophycus, Alethopteris, Hymenophyllites, Ullmannia, Guglielmites, Walchia, and Cardiocarpon. (See pp. 345 *et seq.*)

P.—*Chemical Analyses showing the absence of Phosphoric Acid in the Rocks below the Silurian Deposits.*

In order to ascertain indirectly the presence of phosphoric acid in rocks, my valued friend Dr. Daubeny experimented upon the relative amount of produce obtained from barley sown in various pulverized samples of them, belonging to strata of different geological epochs. He found, that whatever the age of the rock might be, *provided only it belonged to a series in which organic remains were present*, the amount of phosphoric acid present in the crop exceeded considerably that existing in the barley from which it was derived; indicating that the above principle must have been one of the constituents of the rock, as this alone could have supplied it to the plants growing in it. On the other hand, in certain slates which lie below the oldest Silurian rocks in which organic remains have been detected—such, for instance, as the slates of Nant Francon, Llanberis near Bangor, and that north of Dolgelly, or schist taken from the foot of Skiddaw, and a sample of mica-schist from Loch Lomond—the quantity of phosphoric acid present in the crop barely exceeded that existing in the barley sown, indicating the almost entire deficiency of this principle in the rock itself, and consequently leading us to infer, that organic remains never could have existed in it, rather than that the traces of them had been obliterated by subsequent metamorphic action, inasmuch as we have no reason to suppose that any heat which might have affected the strata would have dissipated the phosphoric acid contained in them; many of the Silurian rocks containing phosphoric acid being equally slaty. (See Quarterly Journal of the Chemical Society of London, vol. vii.)

In subsequent researches Dr. Daubeny could detect *no trace of phosphoric acid in specimens from the Longmynd* (which fundamental rock of the Silurian region is no more altered than the overlying Silurian strata), whilst the Ludlow rocks contained as much of it as any of the younger fossiliferous rocks on which he experimented.

The determinations of the chemist are thus in perfect harmony with the con-

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clusions of the geologist and paleontologist, in establishing a decrement of life as we descend through the strata forming the crust of the globe.

Q.—*The Stagonolepis Robertsoni of the Elgin Sandstone.*

Just as this work is about to be published, Professor Huxley, who has examined all the bones and casts of bones belonging to this animal, as well as the footprints probably made by it (see Appendix B), has favoured me with the following notice, in anticipation of a detailed description which will be shortly given to the Geological Society :—

"The remains which have, up to the present time, been discovered, associated with the characteristic scutes of Stagonolepis, or which resemble parts which have been so discovered, sufficiently, to leave no doubt as to their real nature, are the following:—1. Natural casts of portions of three dorsal vertebræ. 2. The impression of the posterior end of a sacral vertebra. 3. A natural cast of seven caudal vertebræ, almost undisturbed, and surrounded by their scutes. 4. A number of impressions of detached caudal vertebræ. 5. Impressions of a femur, and of other bones of the extremities and of the pectoral and pelvic arches.

"The characters of the vertebræ at once remove the animal to which they belonged from all the groups of the Reptilia, except the Crocodilia, Dinosauria, or Thecodont saurians. In some respects the vertebræ approach those both of the Thecodont saurians and of the Dinosauria. They resemble the former in the shape of their bodies, the latter in the remarkable direction of their transverse processes. On the other hand, a careful study of the beautiful series of Teleosaurian remains, which forms a part of the Tesson Collection, lately purchased for the British Museum, has shown me that in every character, save the great angle which the transverse processes of the dorsal vertebræ of Stagonolepis make with the horizon, the vertebræ and scutes of that reptile may be paralleled by those of Teleosauria. The sacrum and the femur are both Crocodilian in their characters. The coracoid resembles that of Hylæosaurus.

"Besides these remains, there can be little doubt that the natural cast of part of a jaw, containing numerous large, conical, recurved teeth, which was found in Findrassie quarry, where no other remains than those of Stagonolepis have yet been discovered, must be referred to the same reptile.

"The characters of the footprints are such, that there is every reason to believe they may have proceeded from such a reptile as Stagonolepis."

The affinity of the Stagonolepis to a high order of reptiles might well induce caution in referring the rock in which its remains, as well as those of the Telerpeton, occur, to so ancient a deposit as the uppermost Old Red or Devonian,—the more so because, if the tract around Elgin alone be examined, the sections will seem to be obscure, owing to great denudation and thick coverings of local drift. At one time, indeed, it occurred to me, that the light-coloured sandstones of Elgin and Burgh Head might pertain to the liassic and oolitic series, of which there are large masses on the north or opposite side of the Moray Frith, as described by myself (Trans. Geol. Soc. 2 ser. vol. ii. p. 293). That hypothesis is, however, set aside, not only by the very different lithological characters of those rocks, but particularly by the fact, that the Elgin and Burgh Head ridges afford no trace of any one of those fossil shells and plants which so abound in the lias and oolites of the opposite coast of Ross, Cromarty, and Sutherland,

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including the white siliceous sandstone of which Dunrobin Castle is built. In short, after my last visit, and on reviewing my notes of 1840, when I made my second visit to the Elgin tract, and also explored the banks of the Findhorn to the south of Forres, I conclude that the yellow sandstones (in parts white) of Morayshire are as fairly linked on to the red conglomerate and sandstones containing the Holoptychius Nobilissimus, as they are to the cornstones of the tract,—the whole constituting a connected and natural series, the details of which will be explained to the Geological Society.

In adhering to my original view respecting the age of the youngest of these Old Red deposits, I am fully aware, that the question may, to a certain extent, remain open for those persons who may suggest that they pertain rather to the Lower Carboniferous, into which Devonian strata pass in many countries, than to the true Devonian group. At present, however, there is no evidence to induce me to place these sandstones in the Carboniferous system; for, although some plants have been found in strata which I believe to be their equivalents in one of the northern headlands of Caithness and in the Shetland Isles, they belong to species never yet observed in the Coal strata. On the other hand, it is fair to state, that the Holoptychii and those fishes which characterize the Uppermost Old Red or yellow sandstone of the South of Scotland have not been found in the Reptiliferous Sandstones of Elgin.—*Nov.* 27, 1858.

R.—*Additional Fossils in the Lingula Flags of Tremadoc.*

MM. Homfray and Ash, who have been recently collecting with vigour fossils around Tremadoc, have enriched the fauna of this zone by important additions. The typical shell, Lingula Davisii, which is found in great quantities, has been so affected by cleavage and pressure as to have assumed the form of several distinct genera—such as Tellina, Modiola, and other bivalve shells. With this shell is associated the Cruziana semiplicata. The highest flags of this zone, as seen at Portmadoc, and which are equivalent to the beds with Olenus (Angelina) subarmatus and O. Sedgwickii, have afforded trilobites which Mr. Salter refers to the genera Asaphus and Ogygia,—these genera being characteristic of the overlying Llandeilo Flags. By this discovery the Lingula Flags are more closely united than ever with the Lower Silurian rocks, of which, indeed, they form the true fossiliferous base. (See pp. 37, 43–48.)

S.—*Additional Notice on the Old Red Sandstone of Morayshire.*

Already in 1828 the tract was so far described by Professor Sedgwick and myself, that we not only united into one geological group its lower red conglomerate and sandstone, intervening cornstones, and superior light-coloured sandstones of Elgin, but we further showed, that the fish-bearing zone of Caithness was traceable to the south-east of Inverness as a thin course of shale; though we there detected no fishes in it.—Trans. Geol. Soc. Lond., 2 Ser., vol. iii. pp. 147, 150, *et seq.*

The remains of fishes were not discovered until nine or ten years afterwards; first, I believe, by the zealous and distinguished Dr. J. Malcolmson. Lady Gordon Cumming, so well known to the readers of the works of Agassiz and Hugh Miller,

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followed up these researches. Dr. Malcolmson, when on leave of absence from the East Indies, detected several of the Caithness fishes at Clune and Lethen Bar, in Nairnshire; and, having followed up his discoveries into Morayshire, presented to the Geological Society a detailed memoir descriptive of these tracts in 1839, as stated p. 558. This paper was recommended by myself to be printed in the Transactions of that body; but, as the author spoke doubtingly respecting the genera and species of his fossil fishes, and did not feel himself competent to describe them, it appears, by a reference which I have just made to the records of the Society, that the order for the publication of the memoir was deferred by the Council, until Agassiz, the great authority on ichthyolites, should have determined the specific characters of the fossils. In the mean time a clear abstract, giving the main features of the labours of Malcolmson (above referred to, p. 558), was published (Proceedings Geol. Soc. Lond. vol. iii. p. 341); and shortly afterwards that accomplished man, having returned to India, fell a victim to his zeal in pursuing geological researches in the jungles of the Bombay Presidency. Doubtlessly it is to be regretted that the original memoir was not completed for publication; but the absence of the author, the want of a scientific description of the fossils, and my own occupations during the next four years, when pursuing researches in Russia, seem to have combined to let the period pass when justice ought to have been done to the field-labours of poor Malcolmson. Every effort will be made to honour his memory.

My respected friend the Rev. G. Gordon, who explored parts of Morayshire and the adjacent country with the deceased, having recently put into my hands the article on this subject before alluded to, which will appear in the January number of 1859 of the 'Edinburgh New Philosophical Journal,' and in which he gives most of the data ascertained by Malcolmson, as taken from a copy of his memoir and from letters addressed to him, and, further, expostulates with the Geological Society for their remissness in respect to that memoir, I take this opportunity—now that I have looked into the subject, and have seen the original paper with its illustrations—of thus explaining the circumstances which led to the memoir not having been printed in full.

In mentioning those persons who, in addition to Hugh Miller, Malcolmson, and others, have done such good geological service on the north-east coast of Scotland, I am bound to go as far back even as my own earliest researches of 1826, and to state, that my friend Mr. George Anderson, of Inverness, has thrown much light upon parts of his native country, and has been of great use to many an explorer besides myself. Mr. Anderson is well known to all tourists as the author of the 'Guide to the Highlands,' in the third edition of which (pp. 344 to 349, &c.) the reader will find an able summary, by the late Mr. Alex. Robertson, of the Geology of the Moray Frith.—*Dec.* 10, 1858.

T.—*Devonian Plants of British North America.*

Professor J. W. Dawson, Principal of M'Gill College, Montreal, has lately determined certain new genera of well-preserved fossil plants from the Devonian rocks of Gaspé, in Canada. His memoir is about to be read before the Geological Society, and illustrates two species of a new Lycopodiaceous genus (Psilophyton), a new Coniferous genus (Prototaxites), and some interesting fragmentary remains of Lepidodendron, Knorria, and Poacites.

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U.—*Foraminifera in Lower Silurian Rocks.*

A curious addition to our acquaintance with the minute fossils of the green sand of the Lower Silurian rocks of Russia has been made by my eminent friend Dr. Ehrenberg, who has discovered that many of the green grains consist of the siliceous casts of Foraminifera. (See British Assoc. Report for 1854.) In the 'Proceedings of the Berlin Academy' for June 1858, the reader will find an account of Ehrenberg's latest researches on the subject,—some figures of these casts, which are considered by him to be new forms,—and references to collateral observations by others.

V.—*Colour retained by Silurian Fossil Shells.*

In the previous edition reference was made (p. 495) to the coloured bands which mark certain paleozoic shells, and the subject has been again mentioned in this volume (p. 216). Thus, the Turbo rupestris, Eichw., from the Lower Silurian limestone of the Chair of Kildare, Ireland, has concentric bands of colour, and an Orthoceras of the Caradoc sandstone exhibits very distinct longitudinal stripes. Now, as Edward Forbes* has shown, that coloured shells, striped or banded, do not usually descend to greater depths than from 15 to 20 fathoms, we may by this fact strengthen the inferences arrived at in the last chapter from other data, that some of the Silurian sea beds, extending over considerable areas, were formed in comparatively shallow water. Mr. Gwyn Jeffreys finds that coloured shells exist at greater depths; so that the conclusion must be adopted with caution.

W.—*Fossil Fishes of the Uppermost Old Red of Fifeshire.*

It has been stated in the Appendix (p. 559), that a fine Holoptychius, very nearly akin to the H. Nobilissimus of Perthshire, occurs in the uppermost yellow sandstone of Dura Den in Fife. My friend the Rev. John Anderson, D.D. (well known by his able work, 'The Course of Creation'), has recently detected many well-preserved ichthyolites in this yellow sandstone of Dura Den, the largest of which was found in the presence of Lord and Lady Kinnaird and myself. Dr. Anderson is now convinced, that this splendid specimen, which measures three feet in length, and is now in the collection at Rossie Priory, is truly the H. Andersoni of Agassiz.

He further informs me, that the yellow sandstones of Dura Den contain ichthyolites of the genera Platygnathus, Diplopterus, Glyptopomus, Holoptychius, Pterichthys (Pamphractus), with a new genus,—an assemblage which shows that certain genera range from the Caithness flags, or central portion of the Old Red group, up into its highest zone. Dr. Anderson's finest specimens are in the British Museum.

X.—*Silurian Rocks of Little Ross Island, Kirkcudbright.*

After describing the rocks of this small island, and showing that they contained Graptolites, both double and single, as well as Orthoceratites, &c., Mr. T. Stevenson, the eminent engineer, correctly inferred, sixteen years ago, that these strata were of Silurian age (Edinb. New Phil. Journ. July 1842). (See Note in this work, p. 175.)

* See Proceedings of the Royal Society, vol. vii. p. 21.

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THE END.

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FIGURES

OF

THE PRINCIPAL SILURIAN FOSSILS,

REPRODUCED FROM THE ORIGINAL

'SILURIAN SYSTEM,'

AND ARRANGED ACCORDING TO THEIR PLACES IN THE GEOLOGIC SERIES.

THE FIGURES OF THE SILURIAN ZOOPHYTES

ALSO ARE HERE REPRODUCED, WHICH WERE OMITTED IN THE FIRST EDITION OF 'SILURIA.'

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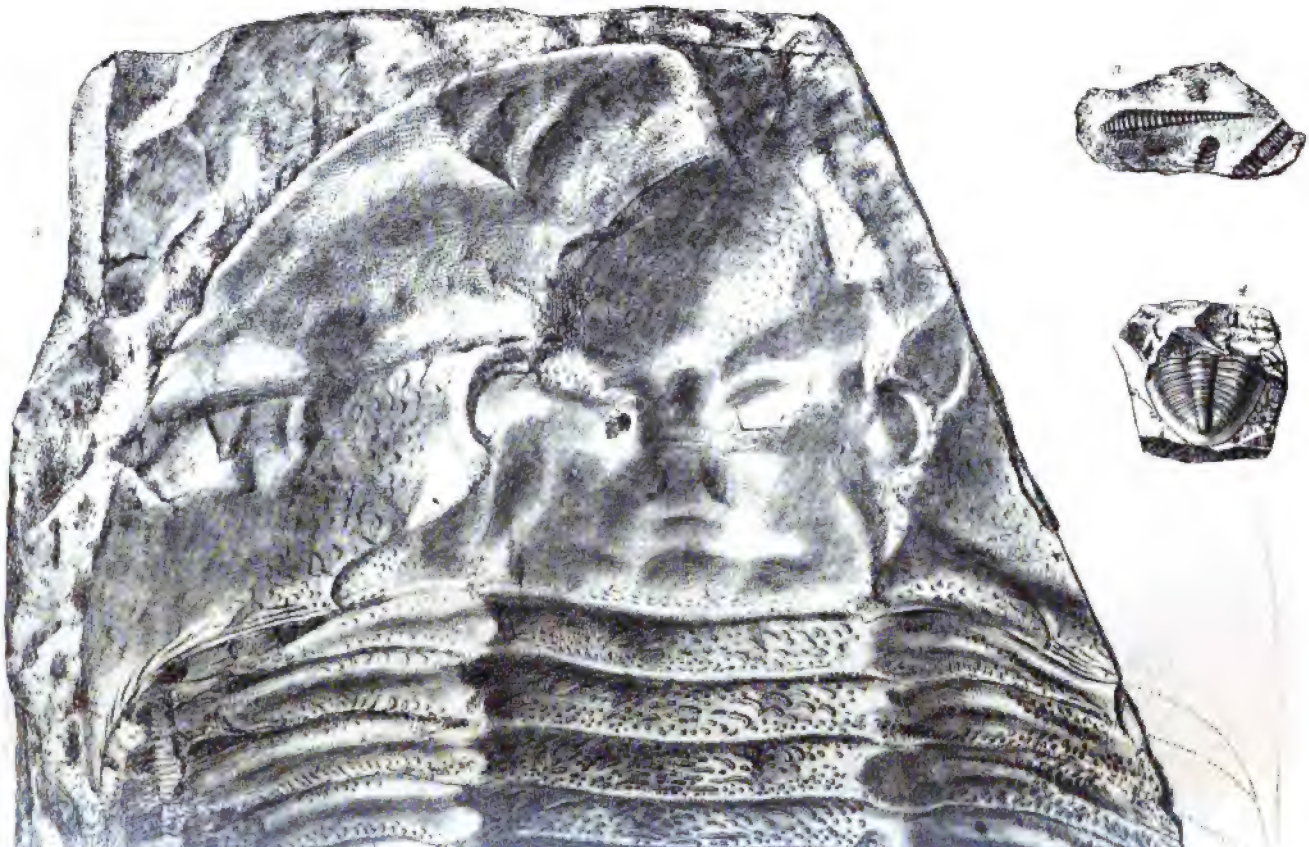
CRUSTACEA, GRAPTOLITES, &c.



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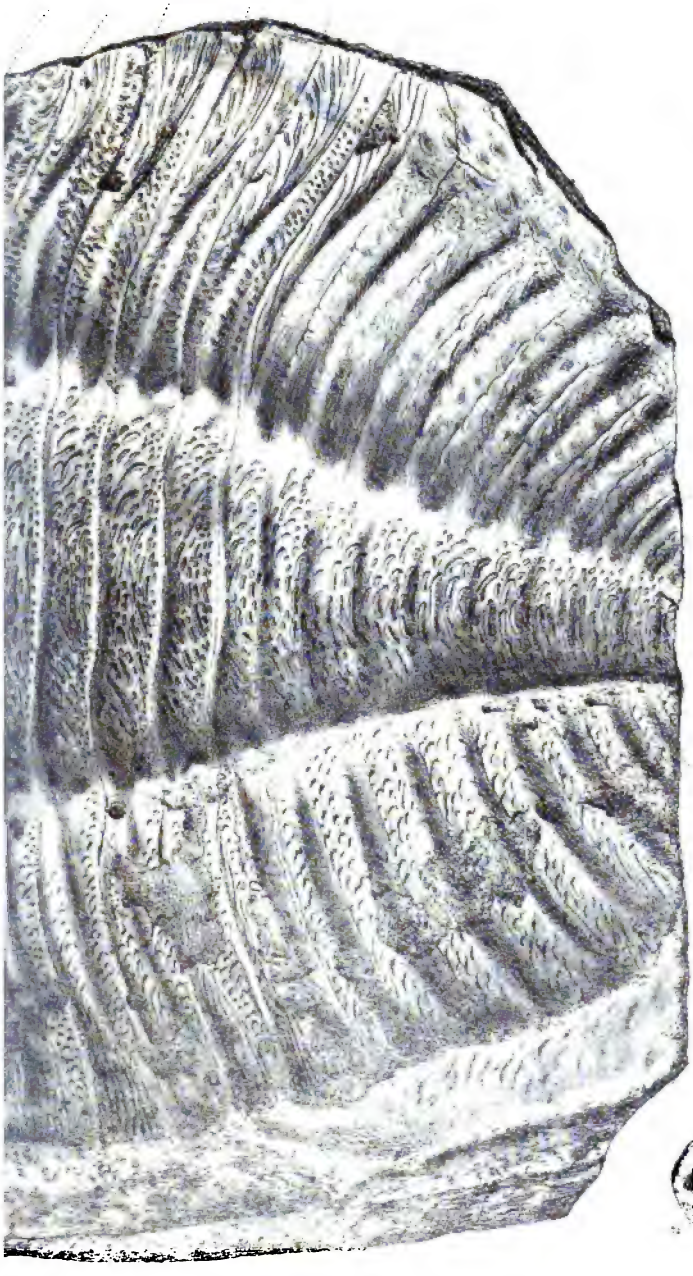

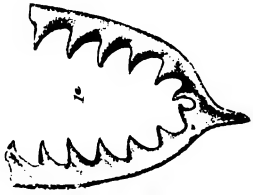

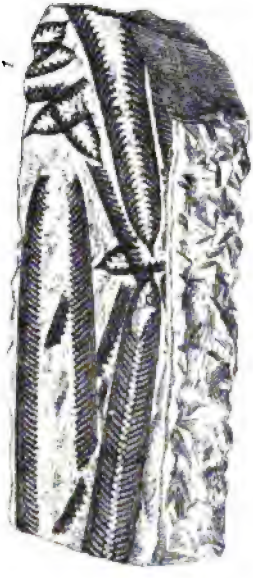

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PLATE I.

[The figures in the Plates I. to XXXVII. are all transferred from the original engravings in the 'Silurian System.' In every case where the old names have been changed, in accordance with more recent nomenclature, the name used in the original work is inserted in brackets, for the purpose of reference.]

LOWER SILURIAN (LLANDEILO AND CARADOC) GRAPTOLITES, ANNELIDES, AND TRILOBITES.

Fig. 1. DIDYMOGRAPSUS (GRAPTOLITHUS) MURCHISONII, Beck. Llandrindod Hills, Radnorshire. Llandeilo flags.

2. DIPLOGRAPSUS (GRAPT.) FOLIACEUS, Murch. Meadow-Town, near Shelve, Shropshire. Llandeilo flags. Accompanied by a small ORBICULA.

3. TENTACULITES ANGLICUS, Salter. (ANNULATUS.) Exterior and internal casts: *a*, portion magnified. Acton Scott, Shropshire. Caradoc sandstone.

4. ASAPHUS TYRANNUS, Murch. Tail of a young specimen. Llandeilo. Llandeilo flags.

5. ————. A very large specimen. From the same locality. The original of this figure is in the British Museum. It is a mould, in sandstone, of the exterior ornamented surface.

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PLATE II.

LOWER SILURIAN (LLANDEILO AND CARADOC) TRILOBITES.

Fig. 1. **ASAPHUS TYRANNUS, Murch.** Tail, and two thorax-segments, of a moderate-sized individual. Llandeilo flags, Llandeilo, Caermarthenshire.

2. **ASAPHUS POWISII, Murch.** Body and tail of a full-sized specimen. Trilobite Dingle, Welshpool. Caradoc sandstone.

3, 4. **HOMALONOTUS (ASAPHUS) VULCANI, Murch.** Cornden Hill, Shropshire. Llandeilo flags.

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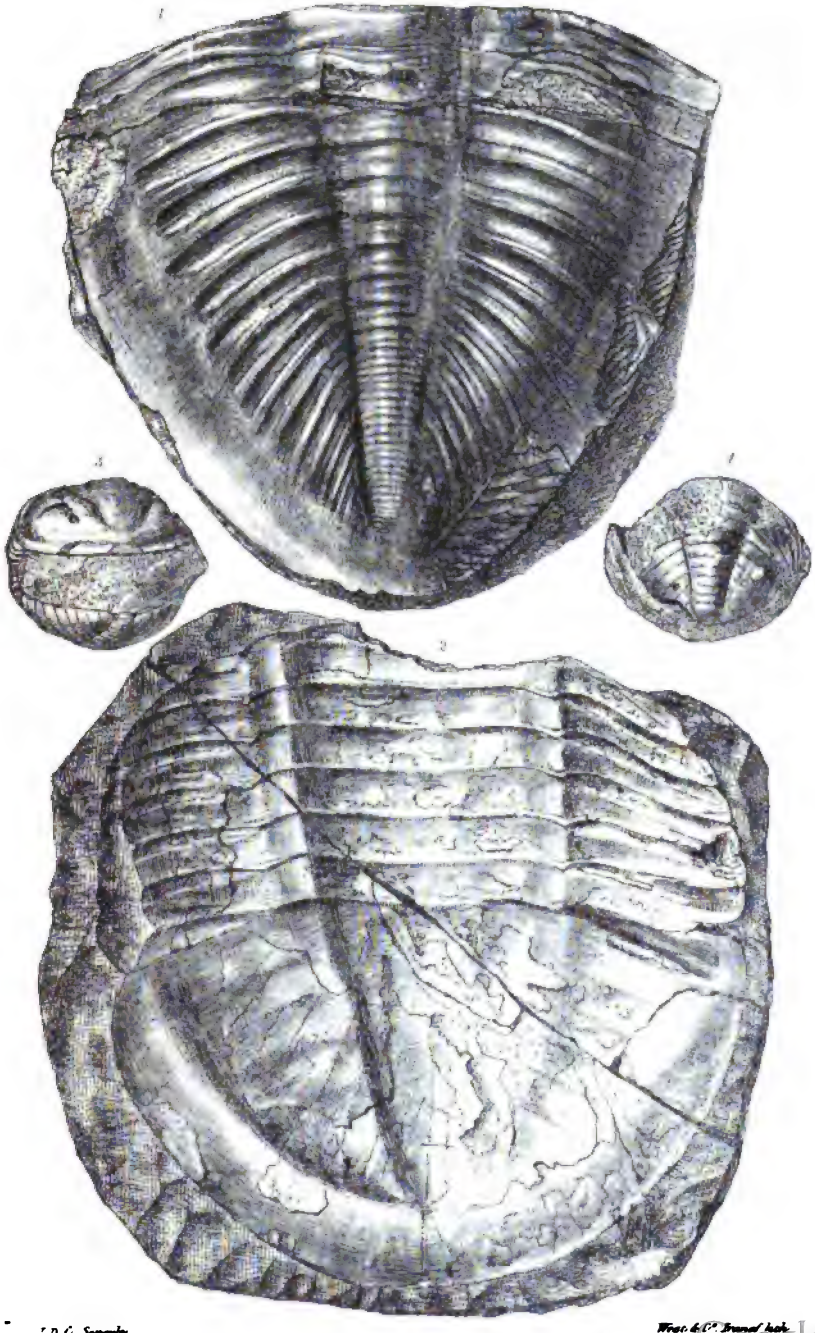
LOWER SILURIAN.

CRUSTACEA.



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LOWER SILURIAN.

Pl. 3.

CRUSTACEA.

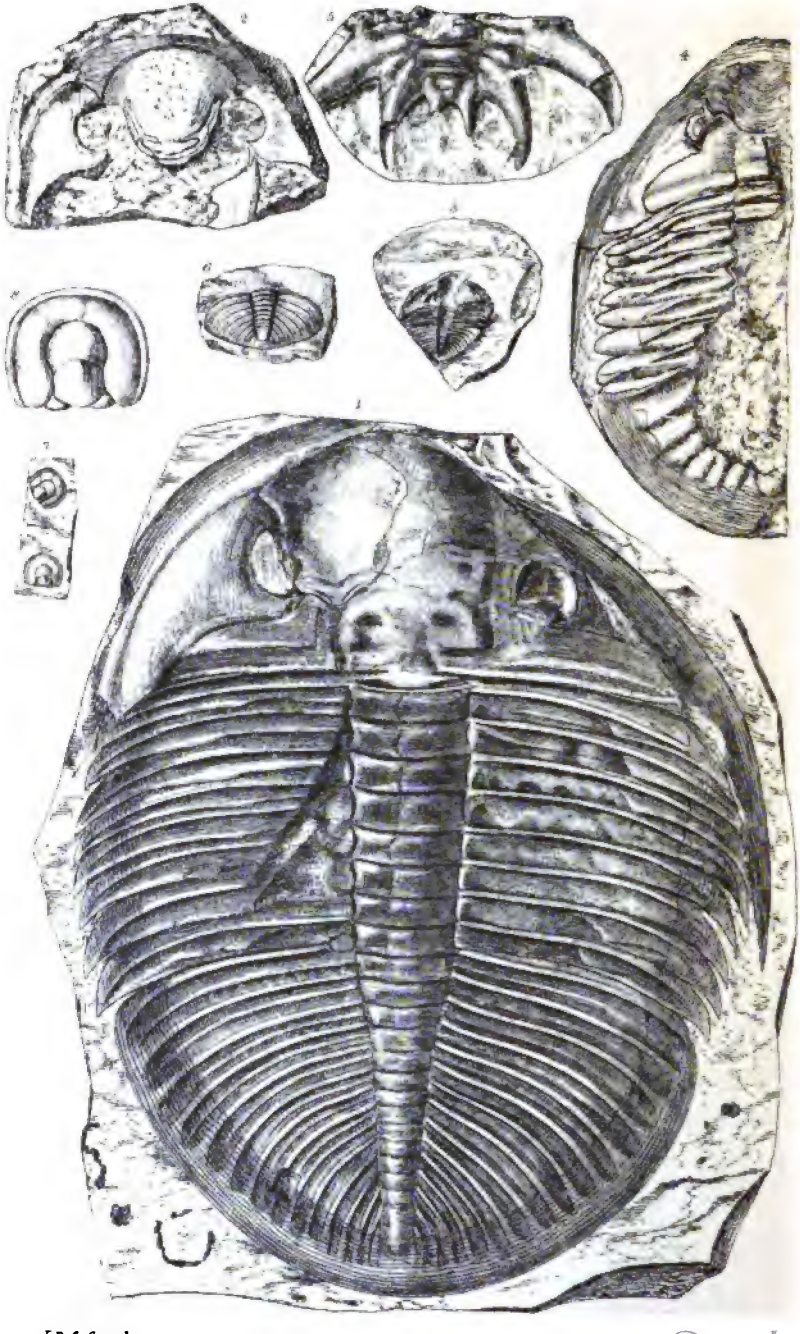

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PLATE III.

LOWER SILURIAN (LLANDEILO AND CARADOC) TRILOBITES.

Fig. 1. OGYGIA (ASAPHUS) BUCHII, Brong. Builth, Radnorshire. Llandeilo flags.

2. ————. Labrum, or upper lip, fixed to the under side of the head. Llandeilo flags.

3. ————. A very young specimen. Builth. (TRINUCLEUS ASAPHOIDES.) Llandeilo flags.

4. OGYGIA (ASAPHUS) CORNDENSIS, Murch. From near the west flank of the Cornden Hill, Shropshire. Llandeilo flags.

5. CHEIRURUS (PARADOXIDES) BIMUCRONATUS, Murch. (Tail only.) Common in the Caradoc or Bala limestone.

6. CALYMENE (ASAPHUS) DUPLICATA, Murch. Wilmington, Salop. Llandeilo flags.

7. AGNOSTUS MACCOYII, Salter. (PISIFORMIS.) Builth, Radnorshire. Llandeilo flags.

8. ————. The head magnified.

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PLATE IV.

LOWER SILURIAN (LLANDEILO AND CARADOC) TRILOBITES.

Fig. 1. STYGINA (OGYGIA) MURCHISONIÆ, Murch. Mount Pleasant, Caermarthen. Llandeilo flags.

2, 4, 5. TRINUCLEUS CONCENTRICUS, Eaton. (CARACTACI.) Welshpool. Caradoc sandstone.

3. ———. Portion of fringe, highly magnified.

6. TRIN. LLOYDII, Murch. Llangadock, Caermarthenshire. Llandeilo flags.

7. TRIN. FIMBRIATUS, Murch. Builth. Llandeilo flags.

8. TRIN. RADIATUS, Murch. Welshpool. Caradoc sandstone.

9, 10. AMPYX (TRINUCLEUS) NUDUS, Murch. Builth, Radnorshire. Llandeilo flags.

11, 12. PHACOPS CONOPHTHALMUS, Bœck. Head. (ASAPHUS POWISII.) Horderley and Acton Scott, Shropshire. Caradoc sandstone.

13, 14. ILLÆNUS PEROVALIS, Murch. N.E. end of Cornden Hill, Shropshire, in Lower Llandeilo flags.

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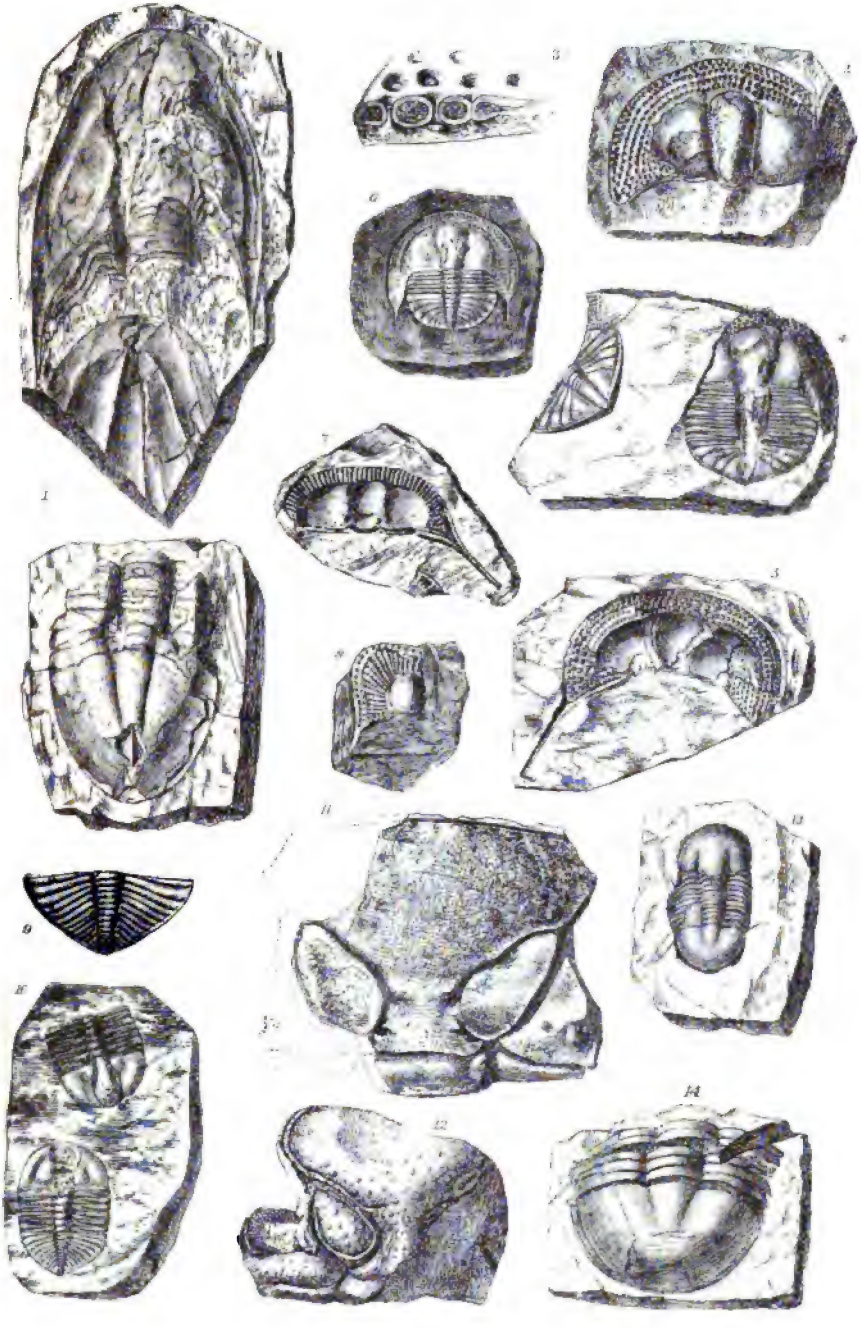
LOWER SILURIAN.

CRUSTACEA.

Pl. 4.



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LOWER SILURIAN.

Pl 5

BRACHIOPODA.

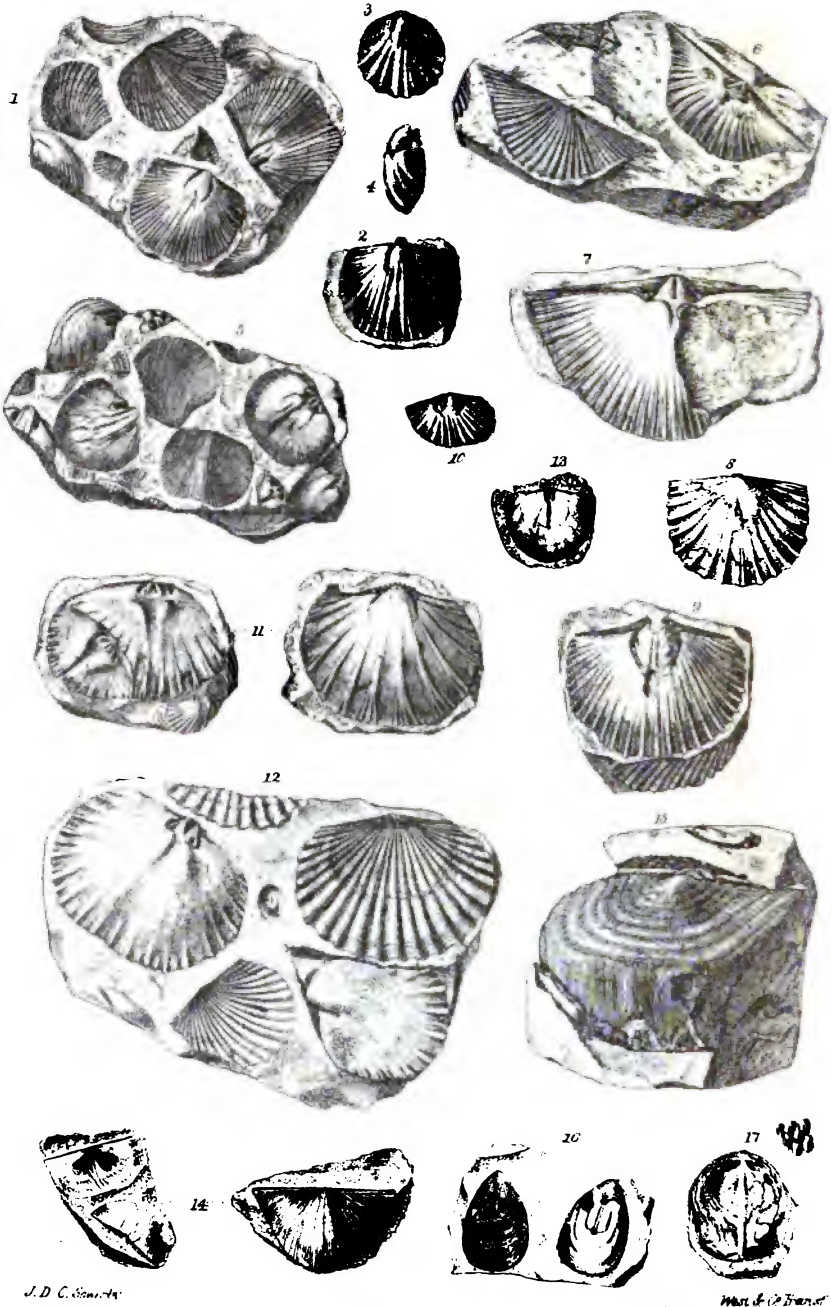

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PLATE V.

LOWER SILURIAN (LLANDEILO AND CARADOC) SHELLS (BRACHIOPODA).

Fig. 1, 2. ORTHIS TESTUDINARIA, Dalman. Horderley; Meifod. Caradoc sandstone.

3, 4. O. (TEREBRATULA) UNGUIS, Sow. Horderley and Cheney Longville, Shropshire. Caradoc sandstone.

5. O. ELEGANTULA, Dalman. Meifod; Bala. Caradoc sandstone.

6. O. (SPIRIFER) ALATA, Sow. Mount Pleasant, Caermarthen. Llandeilo flags.

7, 8, 9. O. CALLIGRAMMA, Dalman. (7. SPIRIFER PLICATUS. 8. ORTHIS CALLACTIS. 9. O. VIRGATA.) Horderley; Bala. Caradoc sandstone.

10. O. RADIANS, Sow. Near Builth. Caradoc sandstone.

11. O. ACTONIÆ, Sow. Acton Scott, Shropshire; Bala. Caradoc sandstone.

12. O. FLABELLULUM, Sow. Hopesay, Shropshire; Bala. Caradoc sandstone.

13. O. TRIANGULARIS, Sow. Chirbury. Caradoc sandstone.

14. LEPTÆNA SERICEA, Sow. Bala; Whittingslow and Horderley, Shropshire; Meifod; Caradoc, Llandeilo, &c., in Llandeilo flags.

15. STROPHOMENA (LEPTÆNA) TENUISTRIATA, Sow. Gaerfawr, Guilsfield, Welshpool. Caradoc sandstone.

16. LINGULA ATTENUATA, Sow. Llandeilo and Shelve. Llandeilo flags.

17. DISCINA PUNCTATA, Sow. (ORBICULA). Cheney Longville, Shropshire. Caradoc sandstone.

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PLATE VI.

LOWER SILURIAN (LLANDEILO AND CARADOC) SHELLS (BRACHIOPODA).

Fig. 1, 2, 3. ORTHIS VESPERTILIO, Sow. Shropshire; Bala. (Including O. BILOBATA.) Caradoc sandstone.

4. STROPHOMENA EXPANSA, Sow. (ORTHIS EXPANSA and O. PECTEN.) Meifod. Caradoc sandstone.

5. ORTHIS ALTERNATA, Sow. Cheney Longville, Shropshire; Bala. Caradoc sandstone.

6, 7. STROPHOMENA (ORTHIS) GRANDIS. Soudley and Acton Scott, Shropshire; Bala. Caradoc sandstone. Coniston.

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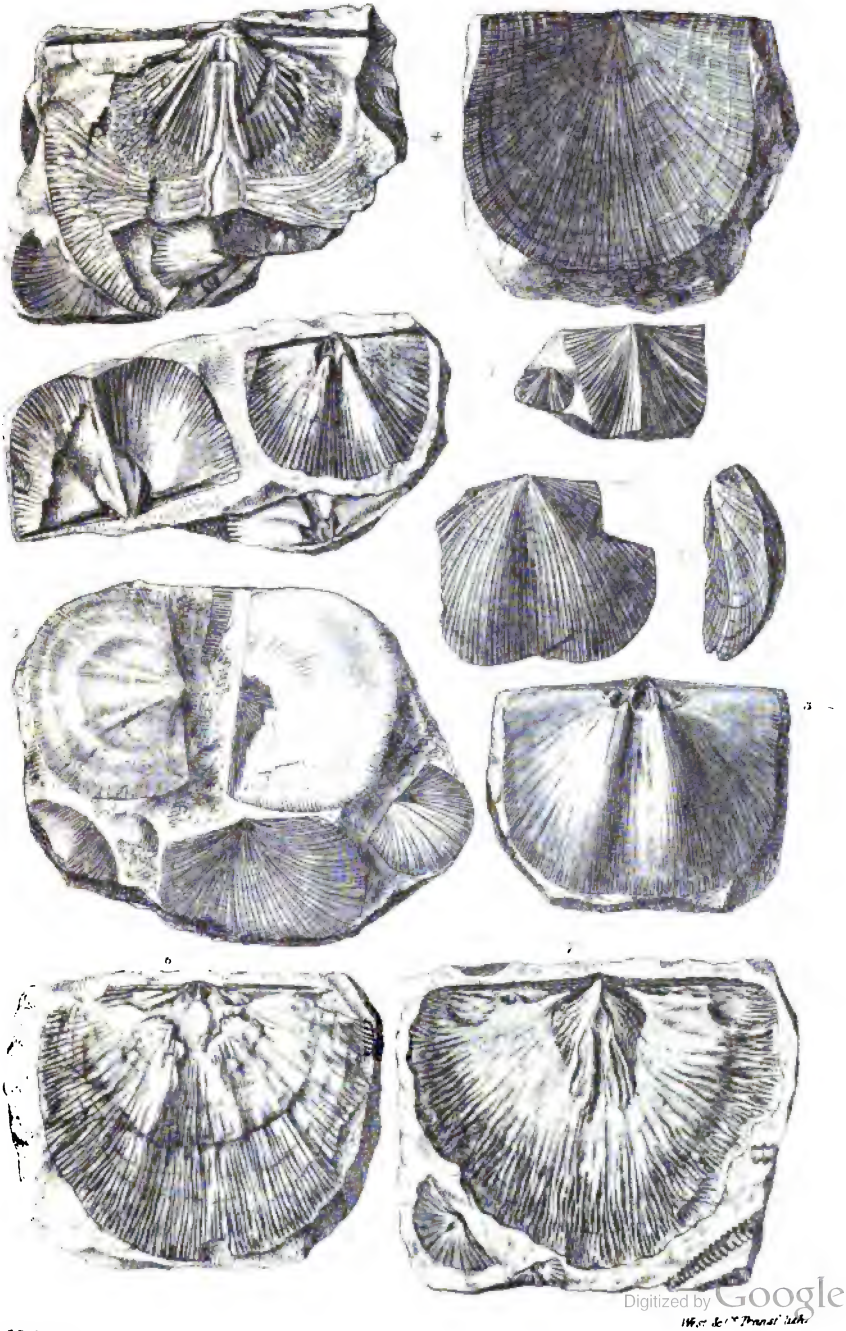
LOWER SILURIAN.

Pl. 6.

BRACHIOPODA.



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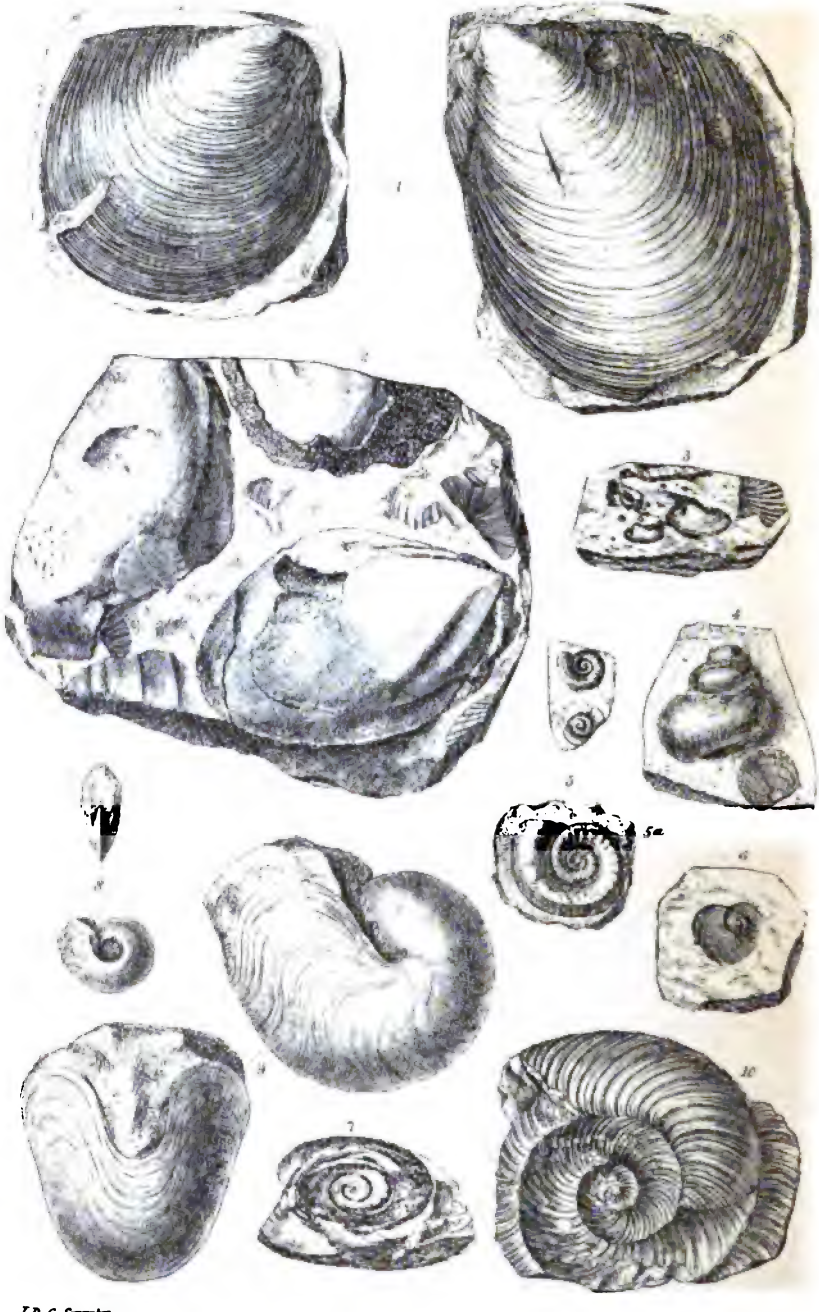
LOWER SILURIAN.

Pl. 7.

LAMELLIBRANCHIATA & GASTEROPODA.



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West & Co. Frans. lith.

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PLATE VII.

LOWER SILURIAN (LLANDEILO AND CARADOC) SHELLS (LAMELLIBRANCHIATA, GASTEROPODA, ETC.).

Fig. 1. MODIOLOPSIS *vel* MODIOLA (AVICULA) ORBICULARIS, Sow. Horderley, Shropshire. Caradoc sandstone.

2. MODIOLOPSIS? (AVICULA) OBLIQUA, Sow. Soudley, Shropshire. Caradoc sandstone.

3. NUCULA LÆVIS, Sow. Pensarn, near Caermarthen. Llandeilo flags.

4. HOLOPEA (LITTORINA) STRIATELLA, Sow. Horderley. Caradoc sandstone.

5. EUOMPHALUS CORNDENSIS, Sow. Leigh Hall, Cornden. (5 *a*, magnified.) Llandeilo flags.

6. BELLEROPHON (EUOMPHALUS TENUISTRIATUS) PERTURBATUS, Sow. Cornden. Llandeilo flags.

7. B. (EUOMPHALUS) PERTURBATUS, Sow. Pensarn, Caermarthen. Llandeilo flags.

8. B. ACUTUS, Sow. Horderley. Caradoc sandstone.

9. B. BILOBATUS, Sow. Horderley, in Caradoc sandstone; also Llandeilo flags, N. Wales.

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PLATE VIII.

LLANDOVERY ROCKS—SHELLS (PENTAMERUS).

Fig. 1, 2, 3. PENTAMERUS OBLONGUS, Sow. Shropshire; Llandovery, etc., in S. Wales. Upper Llandovery rocks.

4. ————. Broader variety (P. LÆVIS, Sow.). The Hollies, Shropshire. Upper Llandovery rocks.

5, 6, 7. P. (ATRYPA) UNDATUS, Sow. Llandovery and Pembrokeshire. Upper and Lower Llandovery.

8. P. (ATRYPA) GLOBOSUS, Sow. Gorllwyn fach, Llandovery. Lower Llandovery rocks.

9, 10. P. (ATRYPA) LENS, Sow. Norbury, May Hill, and S. Wales. Upper and Lower Llandovery.

11. Hinge-portion of the same (P. MICROCAMERUS, M'Coy.) Lickey, Staffordshire.

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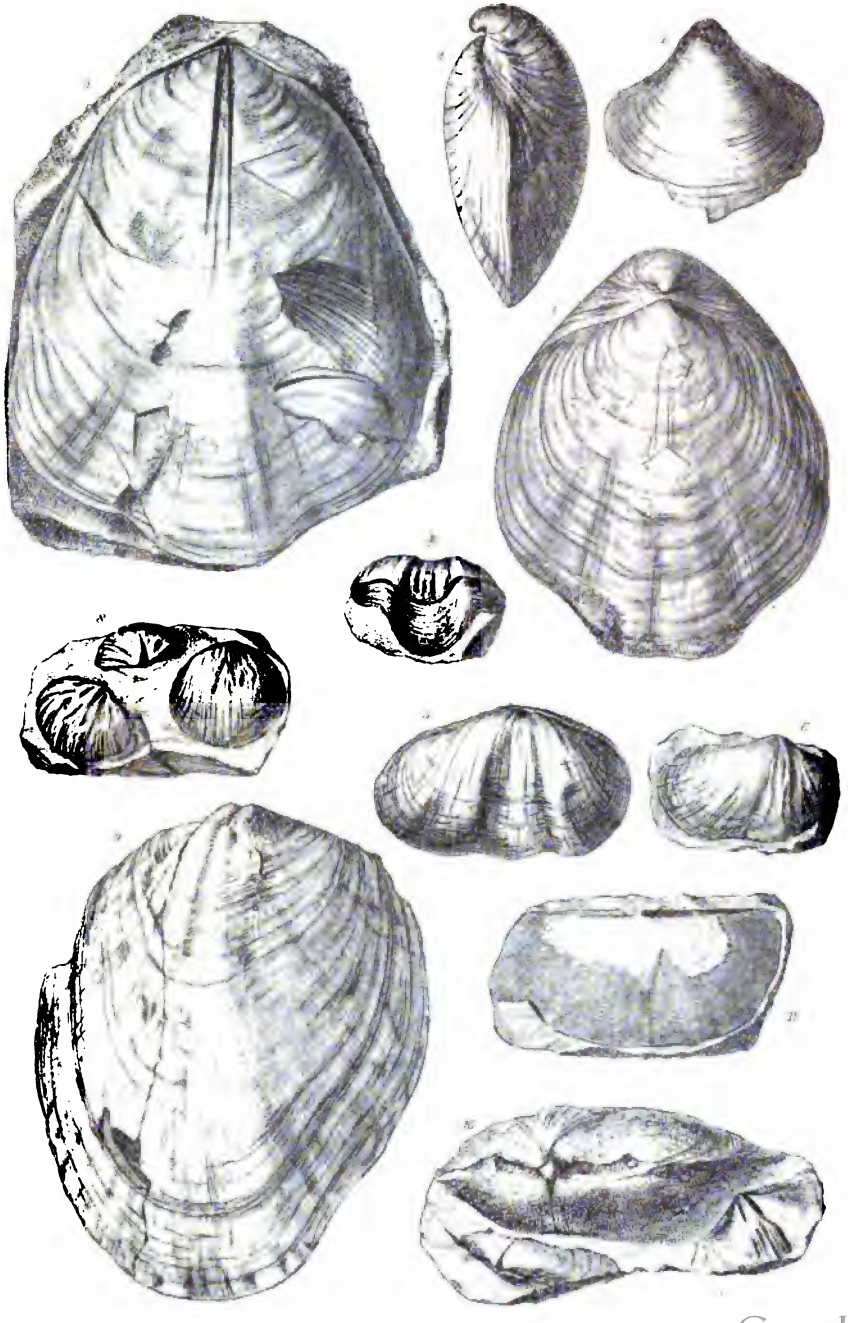
LLANDOVERY ROCKS.

Pl. 8.

BRACHIOPODA.



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LLANDOVERY ROCKS.

Pl. 9

BRACHIOPODA

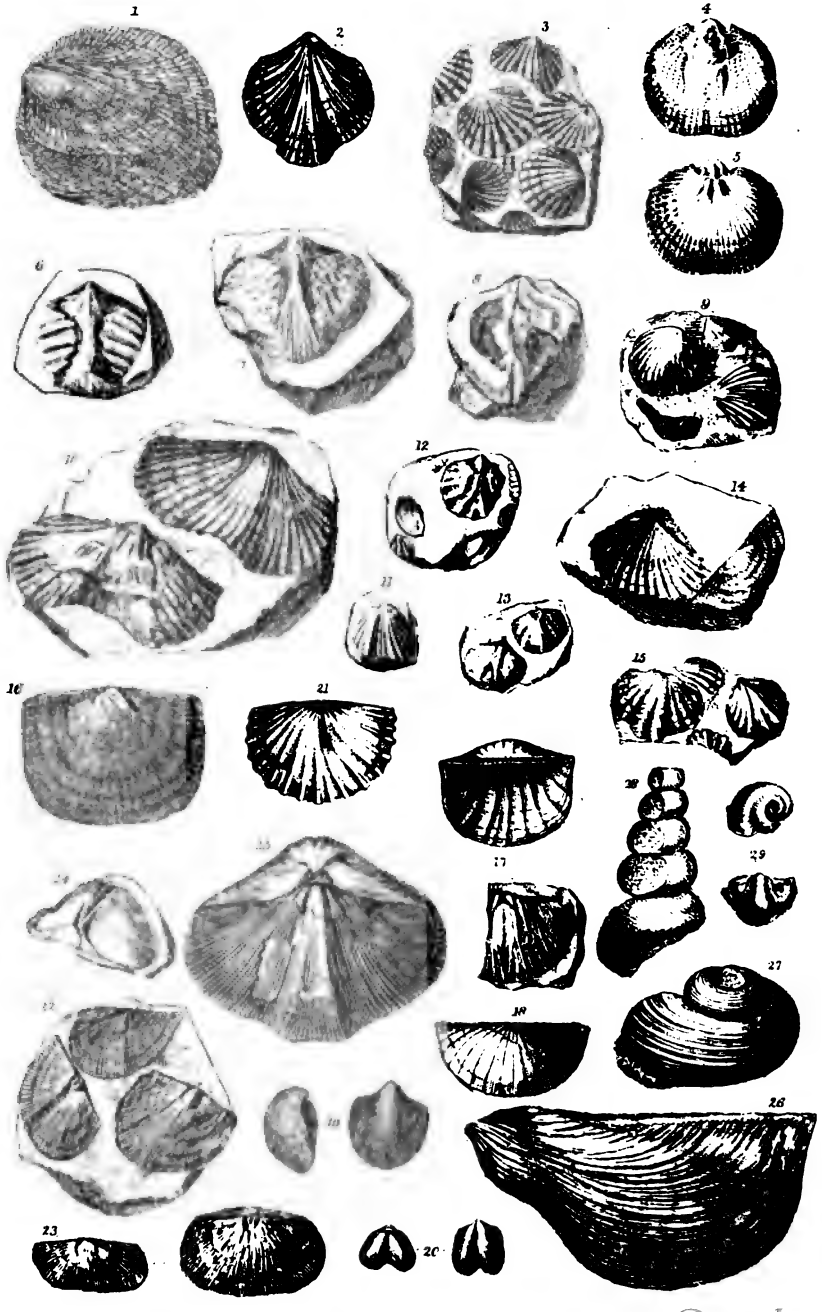

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PLATE IX.

LLANDOVERY ROCKS—SHELLS.

Fig. 1. ATRYPA RETICULARIS, Linn. (AFFINIS.) May Hill, S. Wales, &c.

2. A. MARGINALIS, Dalm. S. Wales. Lower Llandovery.

3. A. HEMISPHÆRICA, Sow. May Hill; Abberley, &c.

4, 5. A. RETICULARIS, Linn., var. ORBICULARIS, Sow. (AFFINIS.) Presteign; also Tortworth.

6, 7, 8. A.? CRASSA, Sow. Llandovery. Lower Llandovery.

9. RHYNCHONELLA NUCULA, Sow. (TEREBRATULA LACUNOSA and T. NUCULA.) Radnorshire; Shropshire. Upper Llandovery.

10. RH. (TEREBRATULA) TRIPARTITA, Sow. Goleugoed. Lower Llandovery.

11. RH. (TEREBRATULA) PUSILLA, Sow. Cefn Rhyddan. Lower Llandovery.

12, 13. RH. (TEREBRATULA) FURCATA, Sow. Bogmine, Shropshire. Upper Llandovery.

14. RH. (TEREBRATULA) NEGLECTA, Sow. Llandovery. Upper Llandovery.

15. RH. (TEREBRATULA) DECEMPLICATA, Sow. Longmynd, Malverns, &c. Upper Llandovery.

16. STROPHOMENA COMPRESSA, Sow. Hope Quarry, Shropshire. Upper Llandovery.

17. LEPTÆNA TRANSVERSALIS, Dalm. Robeston Wathen, Pembrokeshire, &c. Upper and Lower Llandovery.

18. L. SERICEA, Sow. Shropshire, Llandovery, &c. Lower Llandovery.

19. ORTHIS ELEGANTULA, Dalm. Upper and Lower Llandovery.

20. O. BILOBA, Linn. (SINUATA.) S. Wales. Lower Llandovery.

21. O. CALLIGRAMMA, Dalm., var. DAVIDSONI, de Verneuil. May Hill and Malvern. Upper Llandovery.

22, 23. O. PROTENSA (LATA), Sow. Llandovery. Lower Llandovery.

24. SPIRIFER TRAPEZOIDALIS, Dalm. (RADIATA.) Llandovery. Lower Llandovery.

25. SP. PLICATELLUS, Linn., var. RADIATUS. Tortworth, May Hill. Upper Llandovery.

26. PTERINEA (AVICULA) RETROFLEXA, Dalm. Tortworth, Malverns. Upper Llandovery.

27. EUOMPHALUS SCULPTUS, Sow. Tortworth. Upper Llandovery.

28. HOLOPELLA (TURRITELLA) OBSOLETA, Sow. Tortworth. Upper Llandovery.

29. BELLEROPHON TRILOBATUS, Sow. Tortworth. Upper Llandovery.

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PLATE X.

LLANDOVERY ROCKS—TRILOBITES AND SHELLS.

Fig. 1. GLYPTOCRINUS, sp. Exterior and internal casts of the stems. Nash Scar, Presteign. Upper Llandovery.

2. CORNULITES SERPULARIUS, Schloth. Upper Llandovery.

3. TENTACULITES ANGLICUS, Salter. (ANNULATUS.) Interior and exterior. Shropshire. Upper Llandovery. Robeston Wathen. Lower Llandovery.

4, 5. ENCRINURUS PUNCTATUS, Brünn. Hope Quarry, Shelve.

6. PHACOPS STOKESII, M.-Edw. Tortworth, May Hill. Upper Llandovery. [Very characteristic of these rocks.]

7, 8. CTENODONTA (NUCULA) SUBÆQUALIS, M'Coy. Malverns. Upper Llandovery.

9. CT. EASTNORI, Sow. Malverns. Upper Llandovery.

10. RAPHISTOMA LENTICULAR Sow. Sturedge Hill, Worcester. Upper Llandovery.

11. MURCHISONIA (TURBO) PRYCEÆ, Sow. Llandovery. Lower Llandovery.

12. M. (TURBO) ANGULATA, Sow. Mandinam. Lower Llandovery.

13. MACROCHEILUS (BUCCINUM?) FUSIFORMIS, Sow. Presteign. Upper Llandovery.

14. HOLOPELLA (TURRITELLA) CANCELLATA, Sow. Presteign, Malvern, Llandovery. Upper Llandovery.

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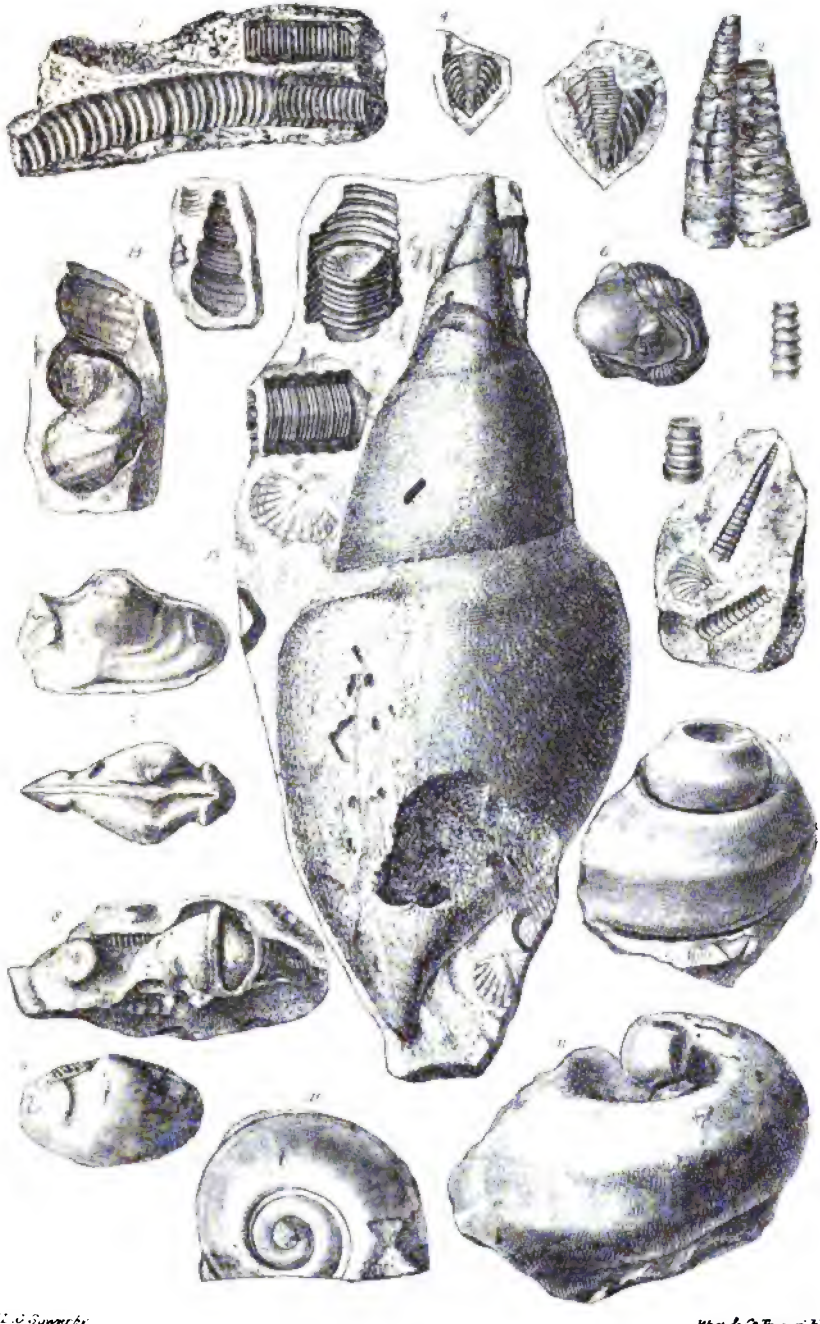
LLANDOVERY ROCKS.

Pl. 10.

SHELLS, TRILOBITES, &c.



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LLANDOVERY ROCKS.

Pl. II.

CEPHALOPODA.

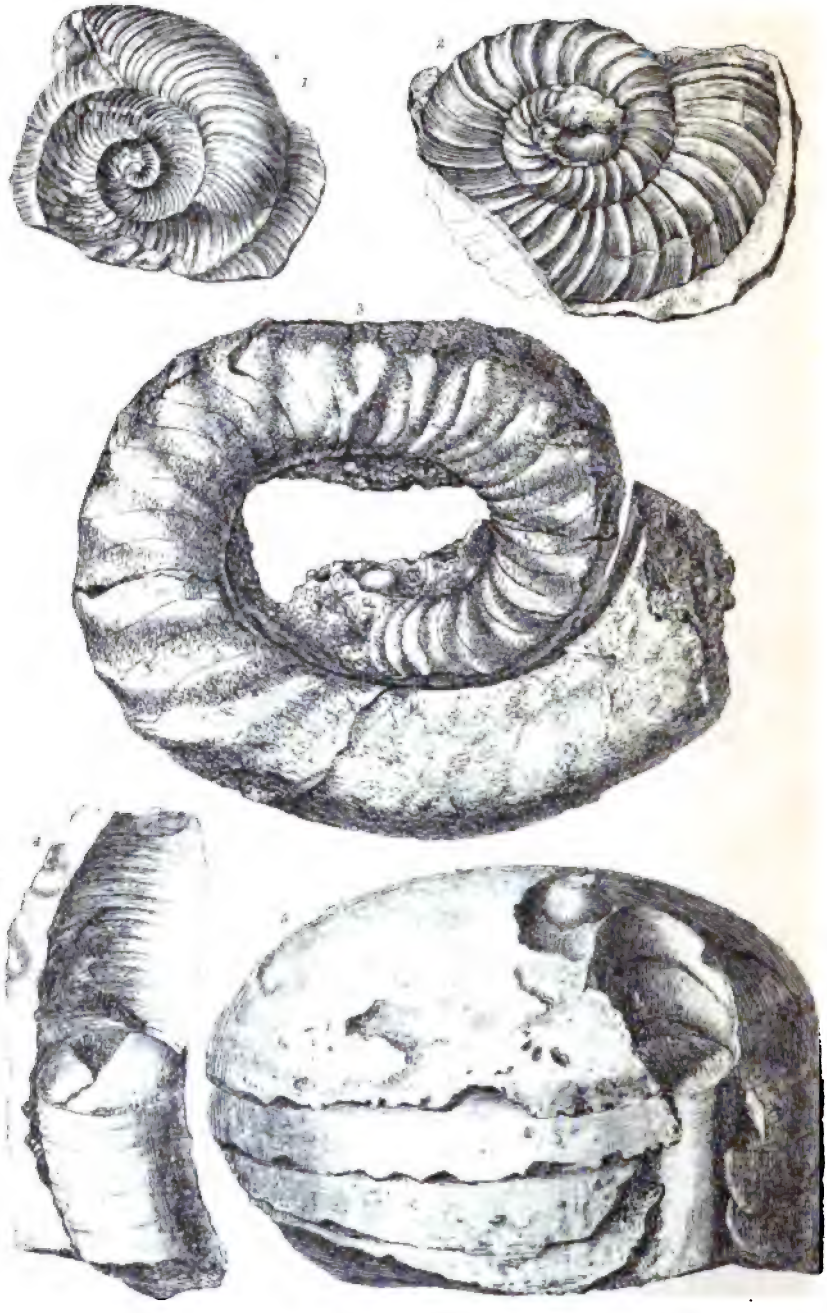

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PLATE XI.

LLANDOVERY ROCKS—SHELLS (CEPHALOPODA).

Fig. 1. LITUITES CORNU-ARIETIS, Sow. Corton, Presteign. Upper Llandovery.

2. ————, var. β. Cefn-y-Garreg, Llandovery. Lower Llandovery.

3. L. (NAUTILUS) UNDOSUS, Sow. Blaen-y-cwm, Llandovery. Lower Llandovery.

4. CYRTOCERAS (ORTHOCERAS) APPROXIMATUM, Sow. Eastnor Park, Malverns. Upper Llandovery.

5. TRETOCERAS (ORTHOCERAS) BISIPHONATUM, Sow. Gorllwyn fach, Llandovery. Lower Llandovery rocks.

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PLATE XII.

UPPER SILURIAN GRAPTOLITES, PLANTS (CALCIPHYTES), ETC.

In the following Plates, U.L. signifies Upper Ludlow.
W.Sh. „ Wenlock shale.
W.L. „ Wenlock limestone.
L.L. „ Lower Ludlow rock.
A.L. „ Aymestry limestone.

[This only signifies, however, that the species mentioned has been figured from specimens from the peculiar band of rock noted; since many of the same shell are common to several subformations. See the Table in the Appendix.]

Fig. 1. GRAPTOLITHUS PRIODON, Bronn. (LUDENSIS.) 1 *a*, magnified. Llanfair, Welshpool. W.Sh. [This occurs throughout from the Snowdon slates to the Upper Ludlow rocks.]

2. ————. A group from a nodule in the Wenlock shale.

3. SPONGARIUM EDWARDSII, Murch. (A Calciphyte.) Bircher Common, Aymestry. U.L.

4. ISCHADITES KŒNIGII, Murch. Probably a Cystidean. Ludlow. L.L.

5. Irregular pyramid, in the mudstone of the Upper Ludlow rock, resulting from the motion of ENCRINITAL STEMS in the soft micaceous matrix: see p. 147 (COPHINUS DUBIUS, König, Sil. Syst.). Ludford. U.L. From later investigations, it appears that this is engraved in a reversed position, the base of the pyramid being in nearly every case upwards.

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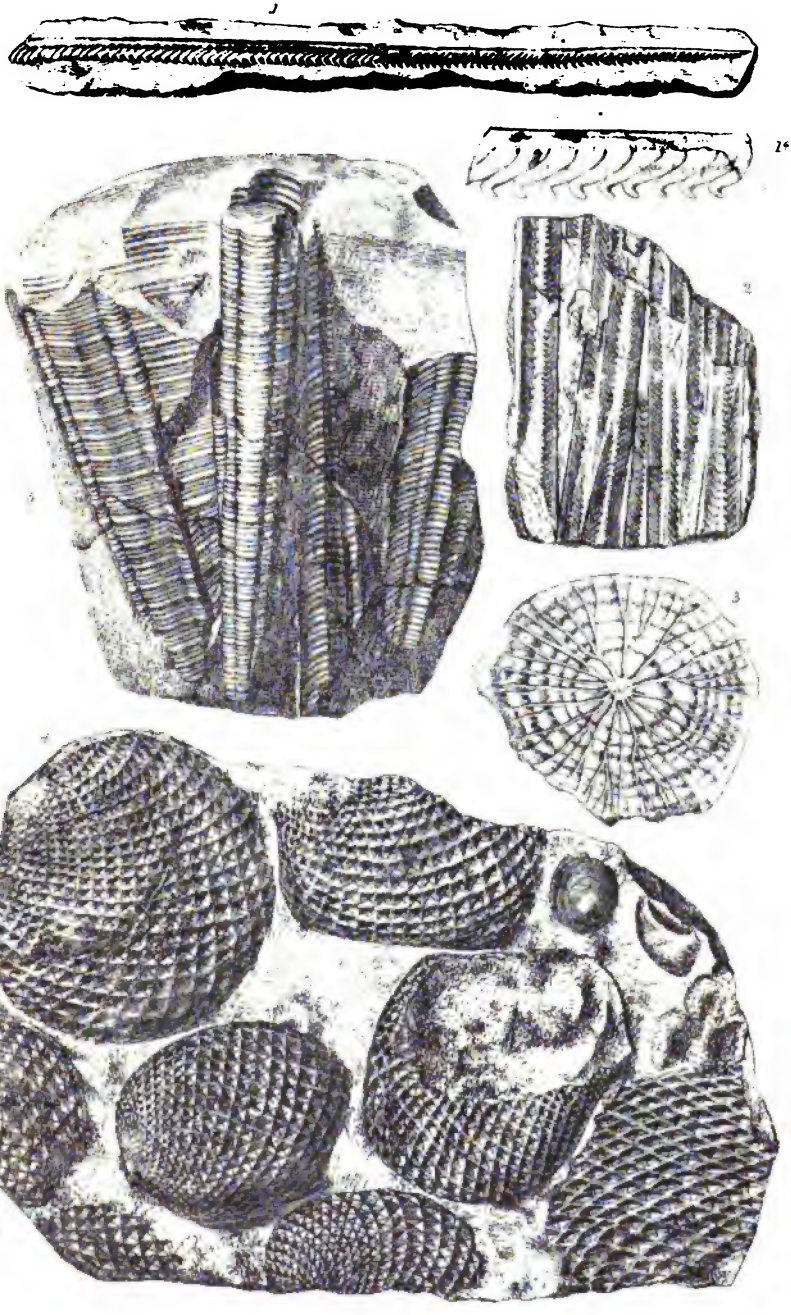
UPPER SILURIAN.

PLG.

GRAPTOLITES AND INCERTÆ SEDIS.



CRINOIDEA.

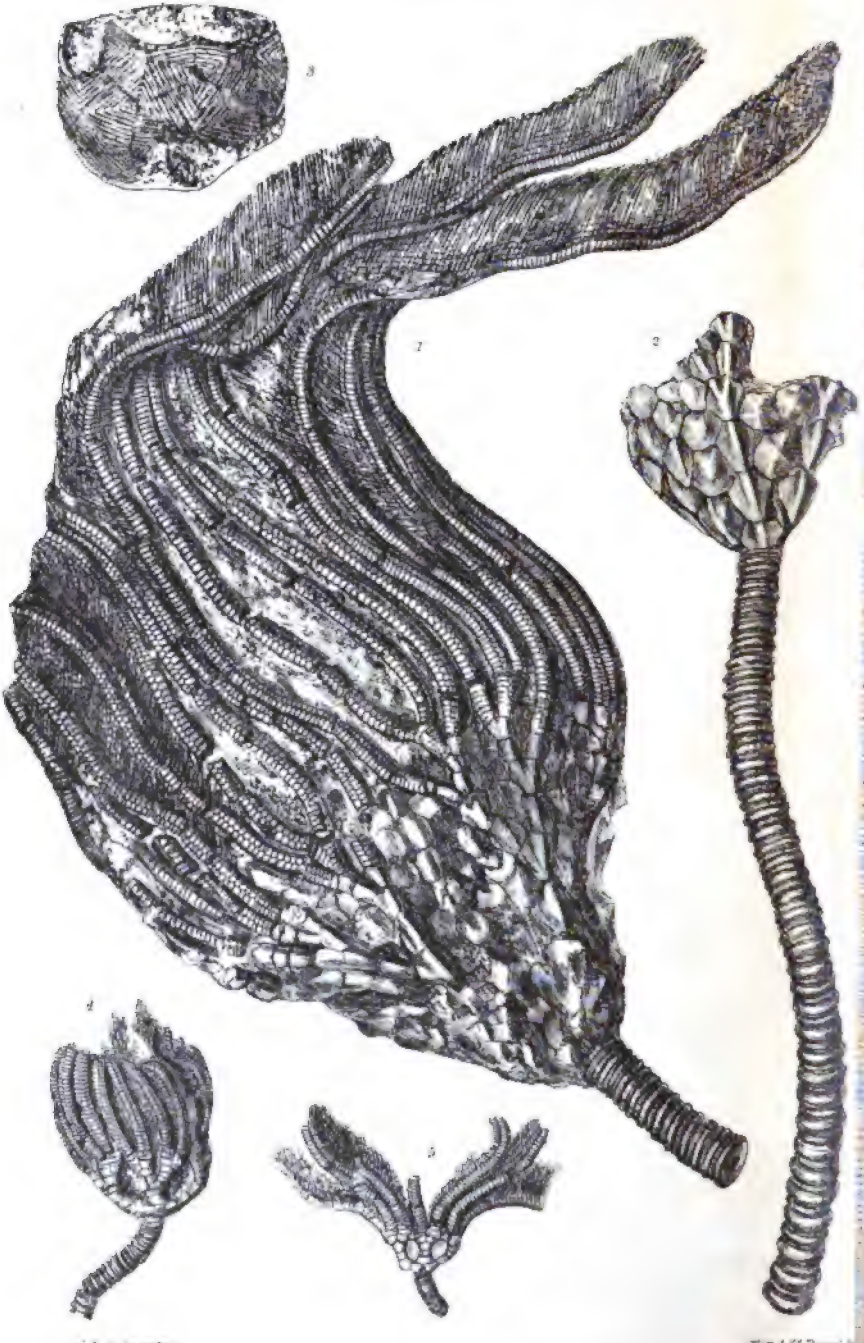


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PLATE XIII.

UPPER SILURIAN CRINOIDEA.

Fig. 1. PERIECHOCRINUS (ACTINOCRAS) MONILIFORMIS, Miller. W.L. Dudley.

2. ———. Stem and pelvis.

3. CROTALOCRINUS (CYATHOCRINUS) RUGOSUS, Miller. Pelvis. W.L. Dudley.

4. DIMEROCRINUS ICOSIDACTYLUS, Phill. W.L. Dudley.

5. D. DECADACTYLUS, Phill. W.L. Dudley.

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PLATE XIV.

UPPER SILURIAN CRINOIDEA.

Fig. 1. MARSUPIOCRINITES CÆLATUS, Phill. W.L. Dudley.

2. EUCALYPTOCRINUS (HYPANTHOCRINITES) DECORUS, Phill. W.L. Dudley.

2*a*. ———. Outlines of the pelvic plates. Dudley.

3. CYATHOCRINUS GONIODACTYLUS, Phill. W.L. Dudley.

4. C. TESSERACONTADACTYLUS, Hisinger. (ACTINOCRINITES SIMPLEX.) W.L. Dudley.

5, 6. TAXOCRINUS (CYATHOCRINITES) TUBERCULATUS, Miller. W.L. Dudley.

7. T. (ACTINOCRINITES?) ARTHRITICUS, Phill. Dudley.

7*. ———. A few joints with tentacles, magnified. W.L.

8. ICHTHYOCRINUS (CYATHOCRINITES) PYRIFORMIS, Miller. W.L. Dudley.

9. PLATYCRINUS (ACTINOCRINITES?) RETIARIUS, Phill. W.L. Dudley.

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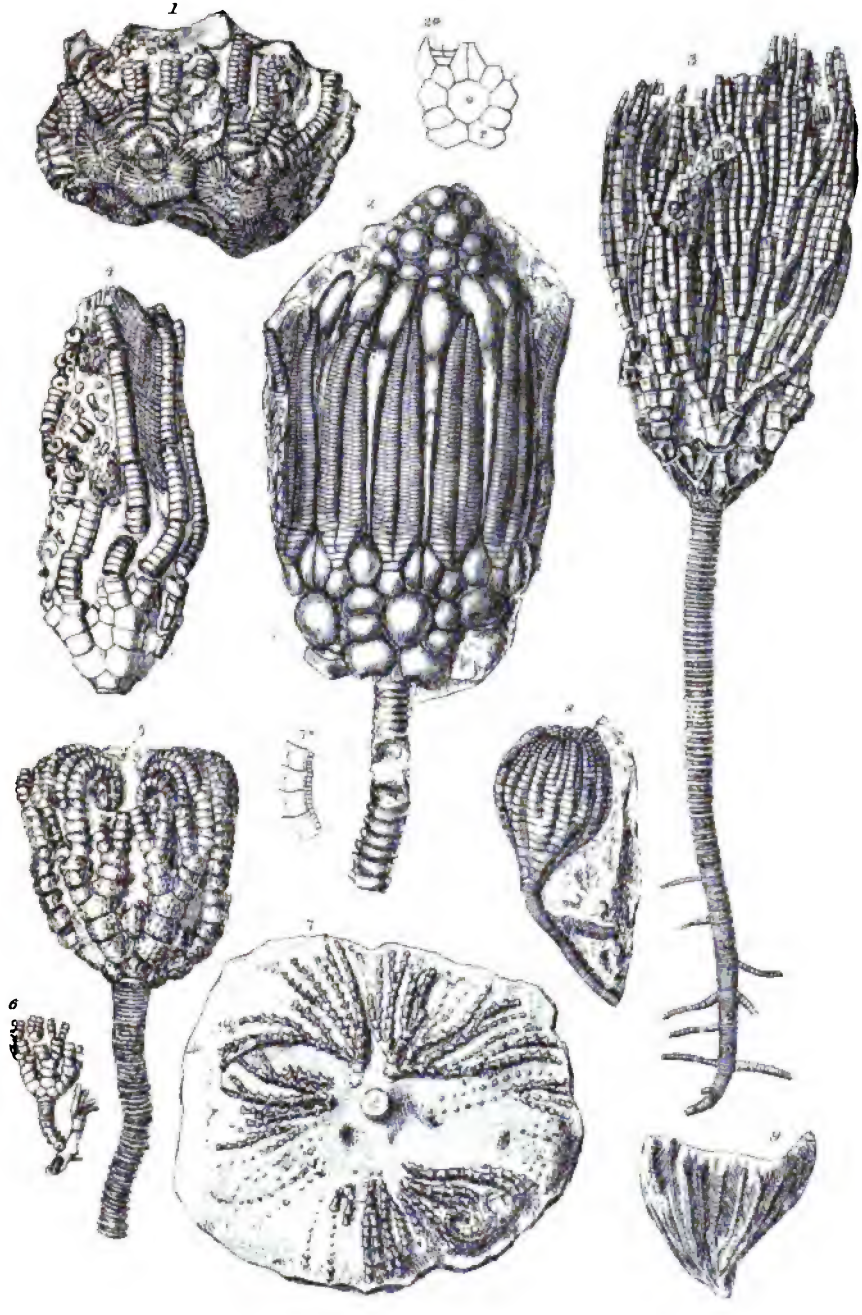
UPPER SILURIAN.

CRINOIDEA.



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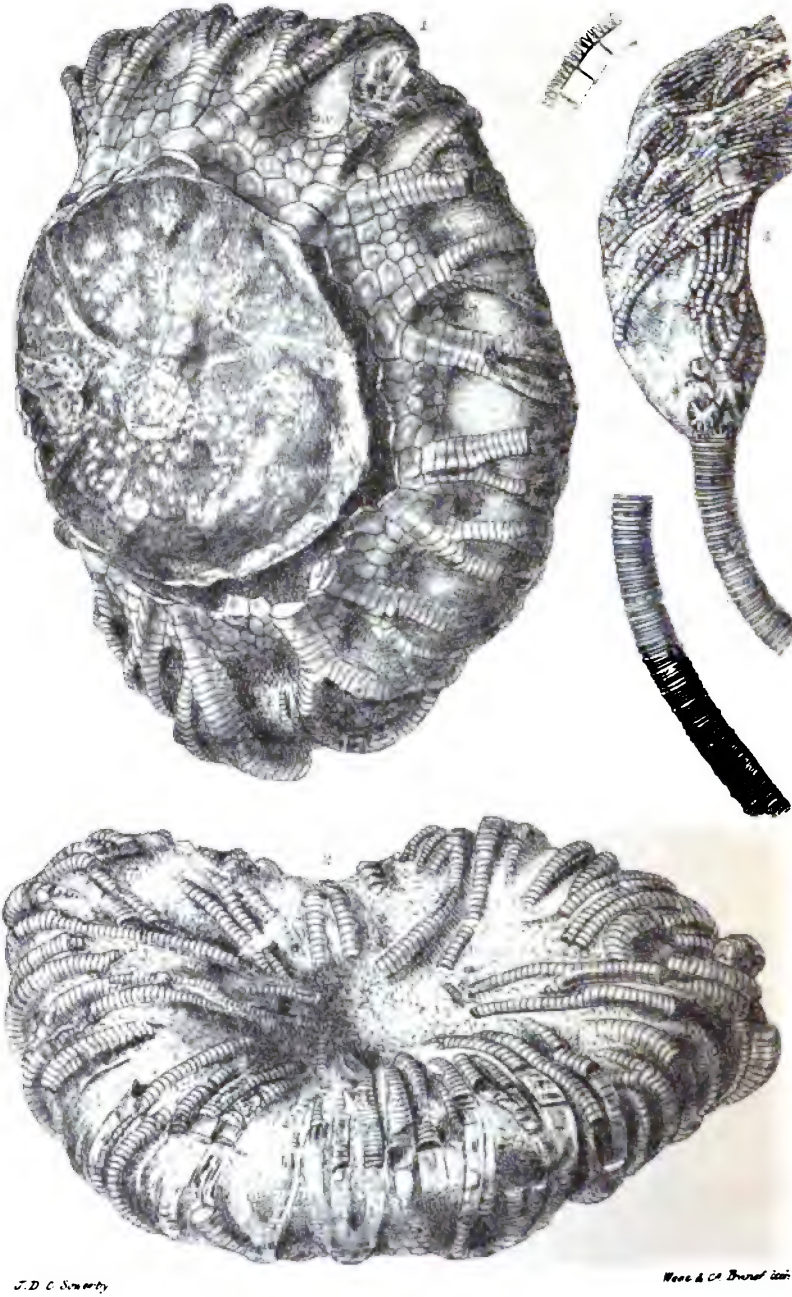
UPPER SILURIAN.

CRINOIDEA.



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Wood & Co. Bristol lith.

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PLATE XV.

UPPER SILURIAN CRINOIDEA.

Fig. 1, 2. GLYPTOCRINUS ? (ACTINOCRINITES ?) EXPANSUS, Phill. W.L. Dudley.

3. CYATHOCRINUS CAPILLARIS, Phill. W.L.

3*a*. ———. A magnified portion of the finger. Wenlock and Dudley.

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PLATE XVI.

UPPER SILURIAN ANNELIDA.

Fig. 1. SERPULITES LONGISSIMUS, Murch. U.L. Ludlow.

2. SPIRORBIS LEWISII, Sow. Natural size, on the inner surface of a Lituites; and 2*a*, magnified. W.L. Ledbury. Common in the Upper Ludlow rock.

3–10. CORNULITES SERPULARIUS, Schloth. W.L. Ledbury.

11. TENTACULITES ORNATUS, Sow. Natural size, magnified, and a section. W.L. Dudley.

12. T. TENUIS, Sow. Natural size and magnified. Usk, Monmouthshire, in Upper Ludlow rock.

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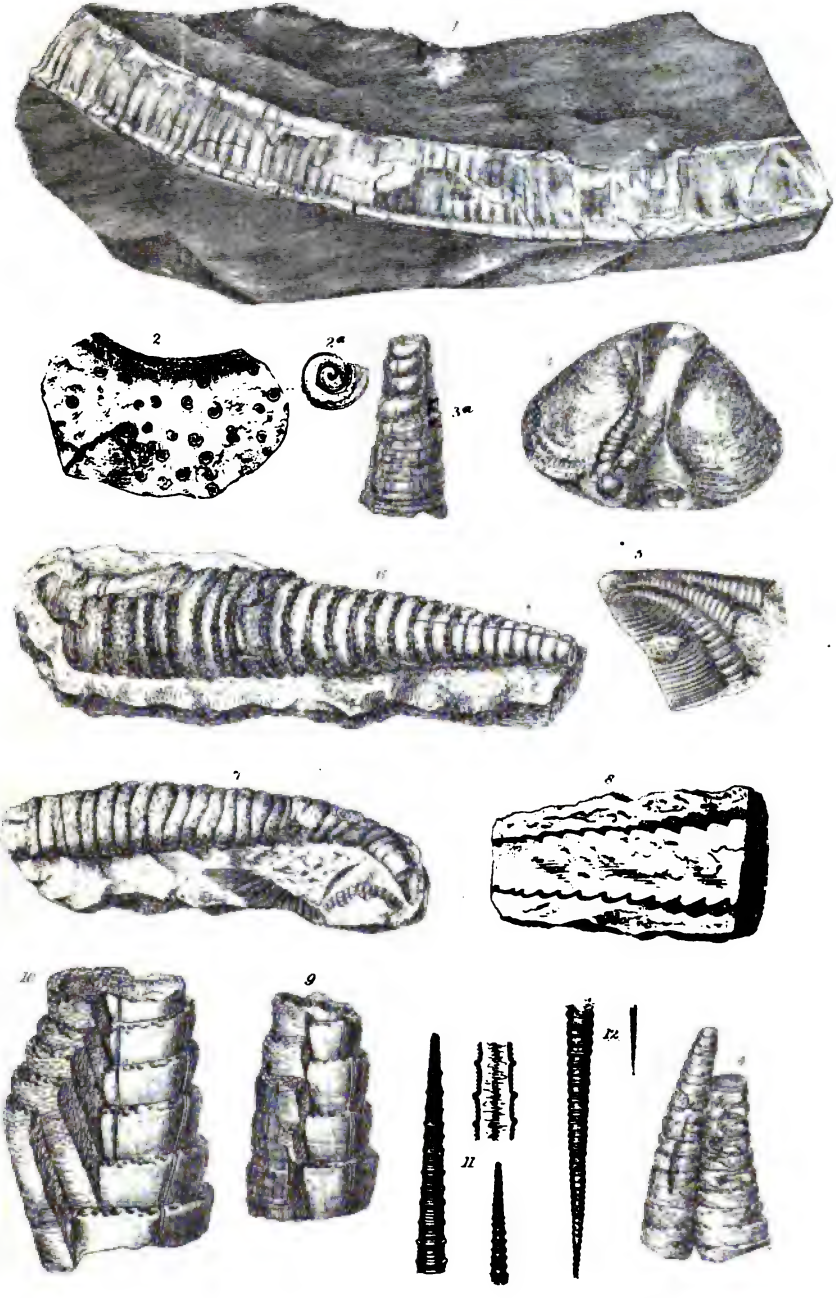
UPPER SILURIAN.

ANNELIDA.

Pl 16.



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UPPER SILURIAN.

PL. 7.

CRUSTACEA.

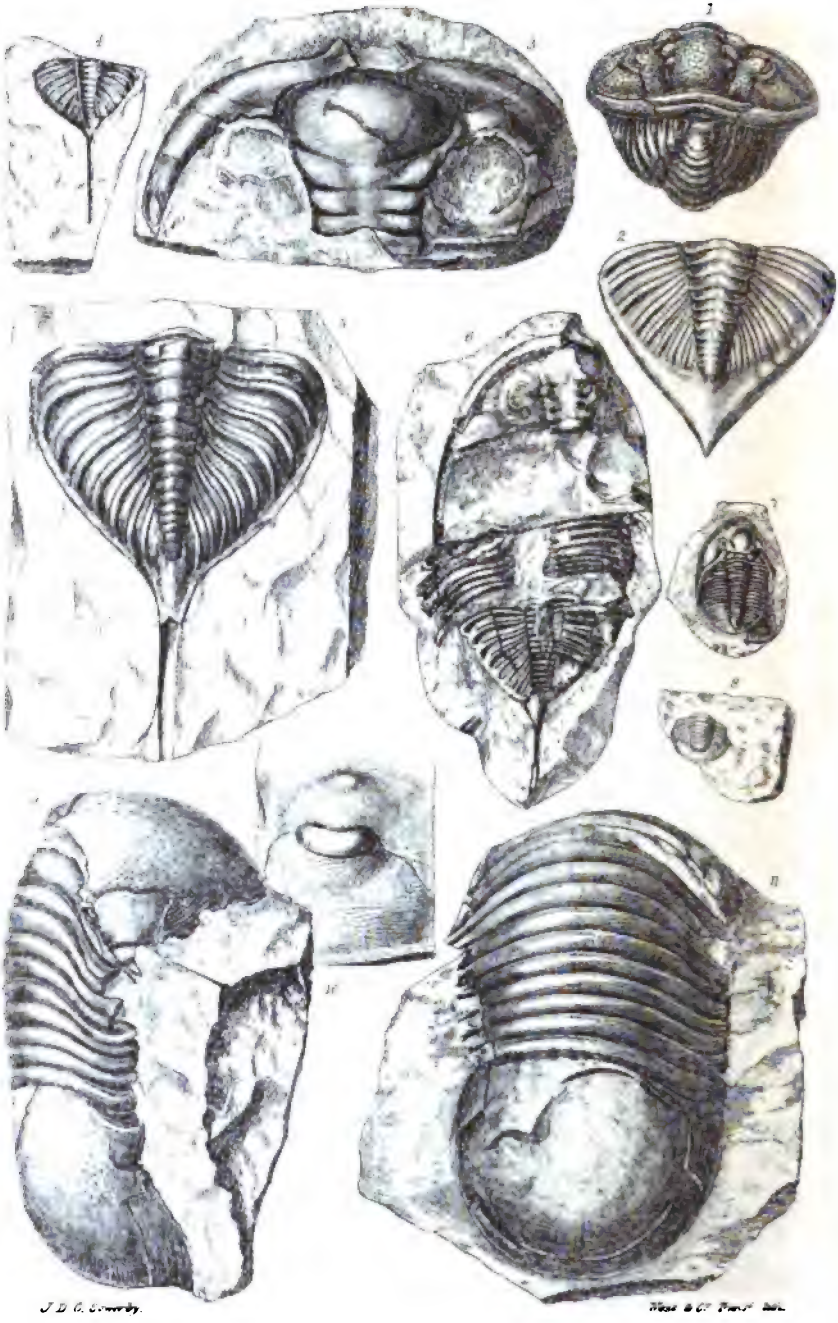

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PLATE XVII.

UPPER SILURIAN CRUSTACEA.

Fig. 1. CALYMENE BLUMENBACHII, Brongn. W.L. Dudley.

2. PHACOPS (ASAPHUS) CAUDATUS, Brongn. W.L. Dudley.

3–6. PH. LONGICAUDATUS, Murch. W.Sh. Wistanstow and Burrington, Shropshire.

7. PROETUS STOKESII, Murch. W.L. Dudley.

8. PROETUS, sp. W.L. Ledbury, Malverns.

9–11. ILLÆNUS (Section BUMASTUS) BARRIENSIS, Murch. 10. Side view of the head and eye. Woolhope Limestone. Barr, Staffordshire; Malverns, &c.

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PLATE XVIII.

UPPER SILURIAN CRUSTACEA.

Fig. 1 PHACOPS (ASAPHUS) CAUDATUS, Brongn. W.L. Shropshire and Dudley.

2, 5. PH. (CALYMENE) DOWNINGIÆ, Murch. W.L. Dudley.

3, 4. ———. Tails of young specimens. (ASAPHUS CAWDORI and A. SUBCAUDATUS.) From Ludlow Rock, Pembrokeshire.

6. PHACOPS STOKESII, Milne-Edw. (CALYMENE MACROPHTHALMA.) W.L. Dudley and Walsall.

7, 8. ACIDASPIS BRIGHTII, Murch. (8. PARADOXIDES QUADRIMUCRONATUS.) W.L. Malverns and Dudley.

9. ENCRINURUS (CALYMENE) VARIOLARIS, Brongn. W.L. Dudley.

10. CALYMENE BLUMENBACHII, Brongn. W.L. Dudley.

11. C. TUBERCULOSA, Salter. (C. BLUMENBACHII, var., Sil. Syst.) W.Sh. Burrington, Shropshire.

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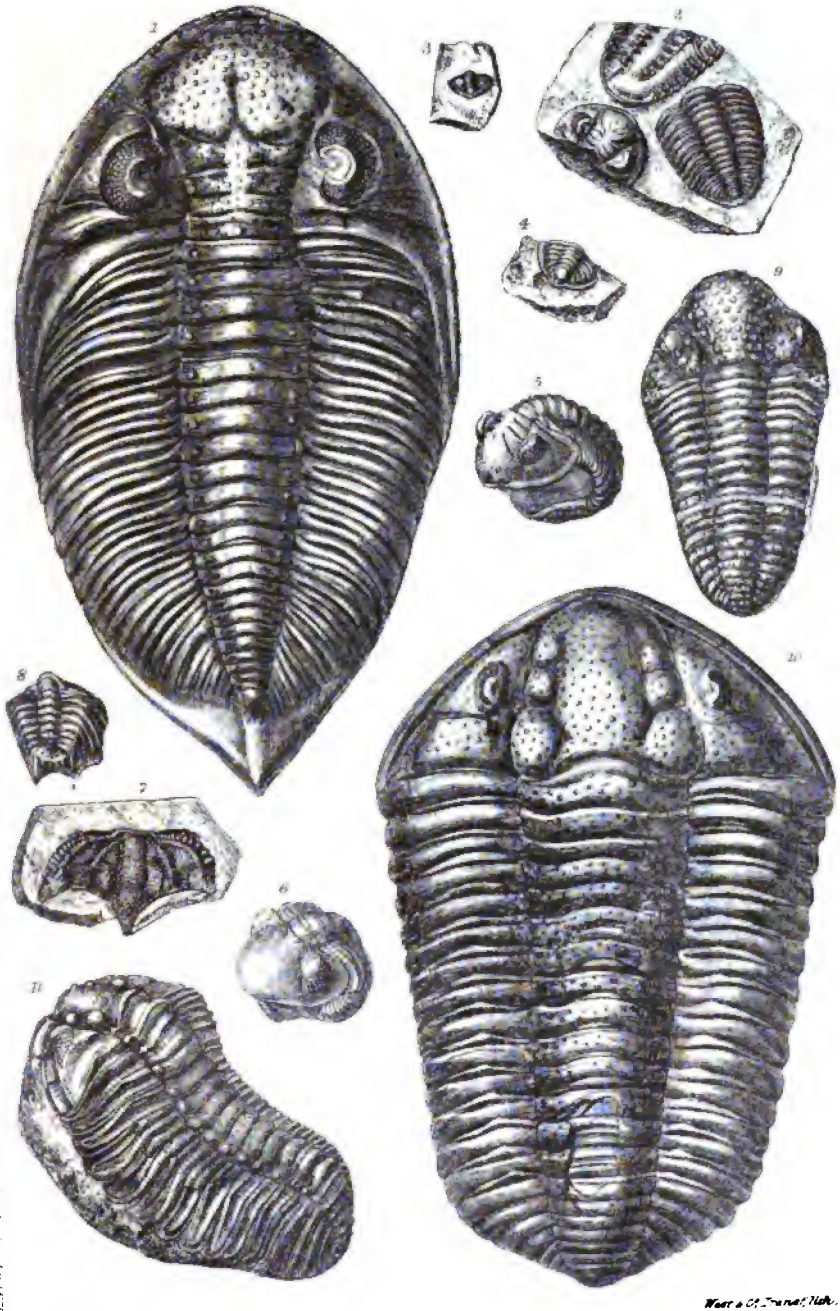
UPPER SILURIAN.

Pl. 18.

CRUSTACEA.



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CRUSTACEA.

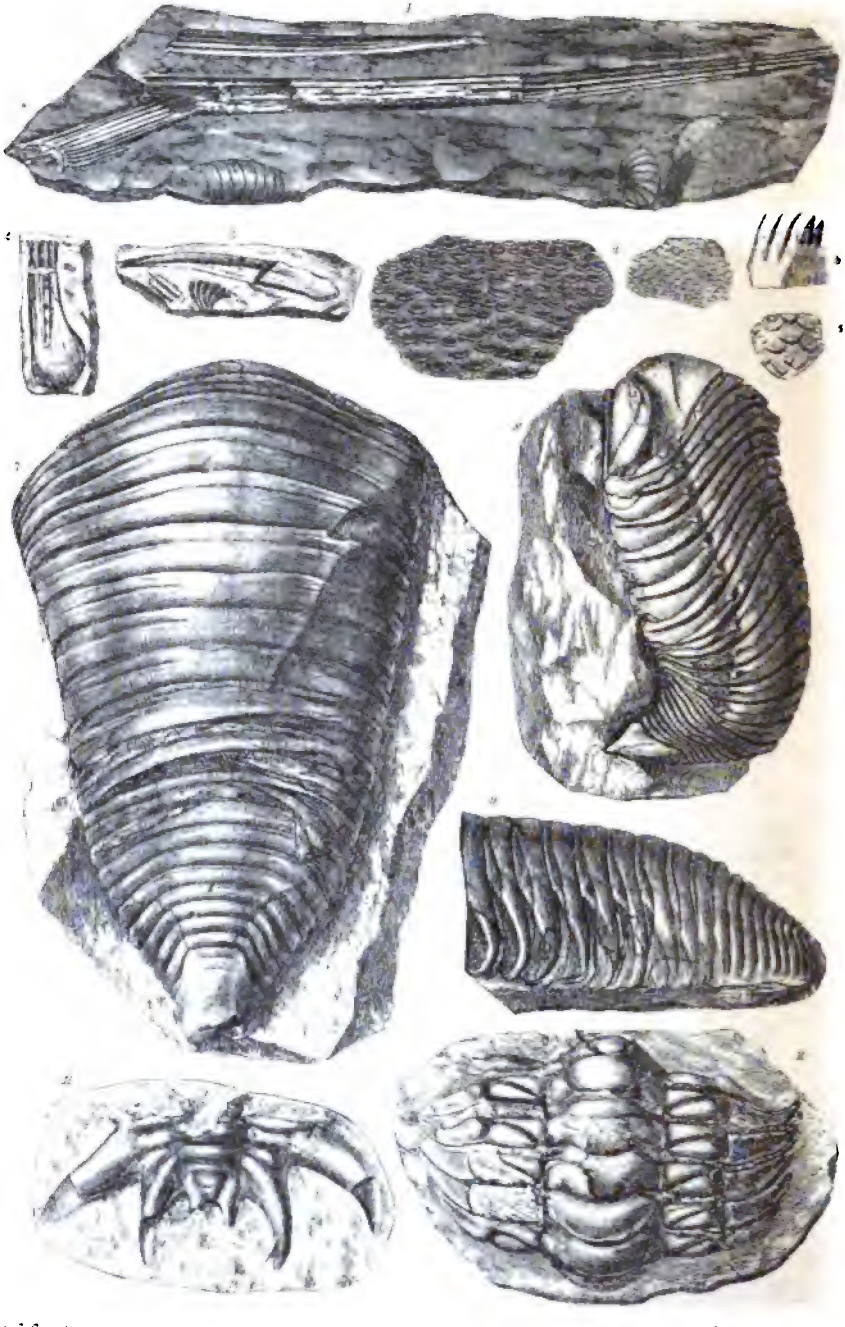

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PLATE XIX.

UPPER SILURIAN CRUSTACEA.

Fig. 1, 2. CERATIOCARIS (ONCHUS) MURCHISONI, M'Coy. Spines of the tail. Uppermost Ludlow rock, near Ludlow.

3. CERATIOCARIS, sp. (ONCHUS.) Fragment of tail-spine.

4, 5. PTERYGOTUS PROBLEMATICUS, Agass. Portions of the carapace, nat. size and magnified. Upper Ludlow. Ludford, in the bone-bed.

6. ————. Portion of the base of one of the jaw-feet. Same locality.

7–9. HOMALONOTUS KNIGHTII (including H. LUDENSIS, Sil. Syst.). U.L. Ludlow.

10, 11. CHEIRURUS (PARADOXIDES) BIMUCRONATUS, Murch. 10, the body-segments; and 11, the tail: the former is placed in an inverted position, the anterior end downwards (it was so engraved in the original work). W.L. Malverns.

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PLATE XX.

UPPER SILURIAN BRACHIOPODA.

Fig. 1. 2. DISCINA (ORBICULA) RUGATA, Sow. U.L. Ludlow.

3. D. (ORBICULA) STRIATA, Sow. U.L. Delbury, Shropshire.

4. CRANIA (PATELLA) IMPLICATA, Sow. W.L. Abberley.

5. LINGULA LEWISII, Sow. A.L. Mary Knoll, Ludlow.

6. L. LATA, Sow. L.L. Elton.

7. L.? STRIATA, Sow. L.L. Near Aymestry.

8. CHONETES (LEPTÆNA) LATA, von Buch. U.L. Ludlow.

9. ORTHIS ELEGANTULA, Dalm., var. ORBICULARIS. (ORBICULARIS.) Exterior and internal cast. U.L. Ludlow.

10. O. CALLIGRAMMA, Dalm., var. RUSTICA. (RUSTICA.) W.L. Valley of Woolhope.

11. O. LUNATA, Sow. Exterior and internal casts of both valves. U.L. Ludlow.

12. O. ELEGANTULA, Dalm. (CANALIS.) W.L. Darmington, Woolhope.

13. O. HYBRIDA, Sow. W.L. Walsall.

14. O. BILOBA, Linn. (SINUATA.) W.L. Walsall.

15. LEPTÆNA LÆVIGATA, Sow. W.Sh. Burrington.

16. L. MINIMA, Sow. Natural size and magnified. W.Sh. Burrington.

17. L. TRANSVERSALIS, Dalm. W.Sh. Buildwas.

18. STROPHOMENA (LEPTÆNA) ANTIQUATA, Sow. W.Sh. Woolhope.

19. S. (LEPTÆNA) EUGLYPHA, Dalm. W.L. Dudley.

20. S. (LEPTÆNA) DEPRESSA, Sow. W.L. Dudley.

21. S. (ORTHIS) FILOSA, Sow. W.Sh. Burrington; Oldcastle.

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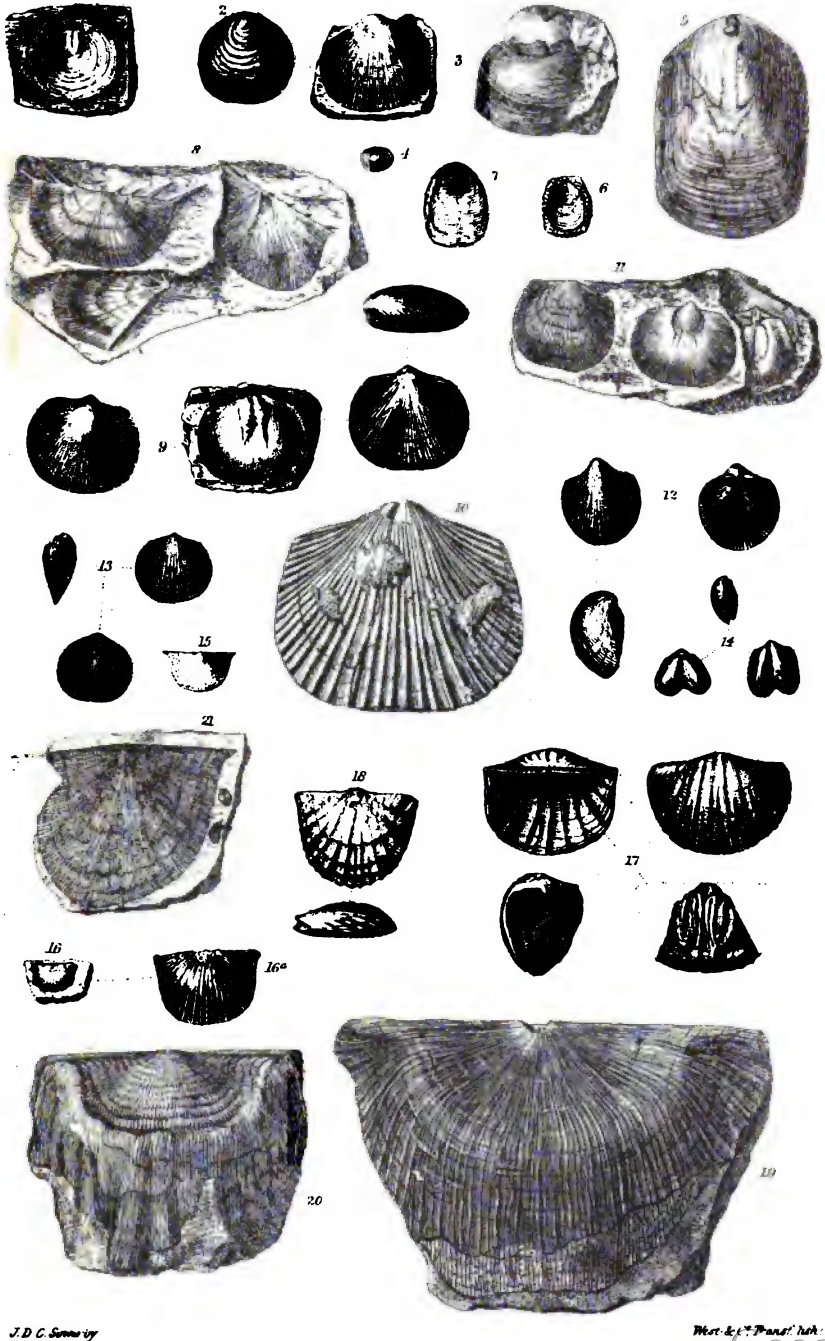
UPPER SILURIAN.

Pl. 20.

BRACHIOPODA



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UPPER SILURIAN.

BRACHIOPODA

Pl. 21.

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PLATE XXI.

UPPER SILURIAN BRACHIOPODA.

Fig. 1. SPIRIFER PLICATELLUS, Linn., var. INTERLINEATUS. (INTERLINEATUS.) A.L. Aymestry.

2. SP. PLICATELLUS, Linn. (RADIATUS.) W.L. Malverns.

3. SP. TRAPEZOIDALIS, Dalm. U.L. Usk.

4. SP. CRISPUS, Linn. W.L. Dudley.

5, 6. SP. ELEVATUS, Dalm. (OCTOPLICATUS.) W.L. Abberley.

7. SP.? PISUM, Sow. W.L. Walsall.

8, 9. PENTAMERUS (ATRYPA) GALEATUS, Dalm. W.L. Wenlock Edge; Dudley; Pembrokeshire.

10. P. KNIGHTII, Sow. A.L. Downton-on-the-Rock; Sedgley.

11. P. KNIGHTII, var. AYLESFORDII. Same localities.

12, 13. ATRYPA RETICULARIS, Linn. (AFFINIS.) A.L., W.L. Shropshire; May Hill; Dudley, &c. Woolhope L. Woolhope.

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PLATE XXII.

UPPER SILURIAN BRACHIOPODA.

Fig. 1, 2. RHYNCHONELLA NUCULA, Sow. (TEREBRATULA LACUNOSA and T. NUCULA.) U.L. Radnorshire; Shropshire.

3. R. (TEREBRAT.) PENTAGONA, Sow. U.L. Delbury, Shropshire.

4. R. BOREALIS, Schloth. (T. LACUNOSA.) W.L. Wenlock Edge.

5. ———, var. DIODONTA. (T. BIDENTATA.) W.L. Dudley.

6. R. (TER.) CRISPATA, Sow. Woolhope Limestone, Nash Scar.

7. R. (TER.) CREBRICOSTA, Sow. W.Sh. Tynewydd, Llandovery.

8. RETZIA (TER.) CUNEATA, Dalm. W.L. Dudley.

9. RHYNCHONELLA (TER.) SPHÆRICA, Sow. W.Sh. Walsall.

10. R. DEFLEXA, Sow. (TER. DEFLEXA and T. INTERPLICATA.) W.L. Wenlock Edge. W.Sh. Walsall.

11. R. (TER.) STRICKLANDI, Sow. W.L. Longhope. W.Sh. Usk.

12. R. (TER.) NAVICULA, Sow. A.L. Ludlow; Usk. W.Sh. Builth.

13. R. (TER.) WILSONI, Sow. A.L. Aymestry.

14. TEREBRATULA? LÆVIUSCULA, Sow. W.Sh. Tynewydd, Llandovery.

15. RHYNCHONELLA DIDYMA, Sow. (TER. DIDYMA and T. CANALIS.) U.L., A.L. Usk, Abberley.

16. R. (ATRYPA) OBOVATA, Sow. L.L. Malverns.

17. R. (ATRYPA) DEPRESSA, Sow. W.Sh. Stump's Wood, Malverns.

18. R. (ATRYPA) ROTUNDA, Sow. W.L. Wenlock Edge.

19. ATRYPA (TER.) MARGINALIS, Dalm. (including T. IMBRICATA). W.L. Wenlock, &c.

20. ATHYRIS TUMIDA, Dalm. (TENUISTRIATA.) W.L. Malverns.

21. PENTAMERUS (ATRYPA) LINGUIFER, Sow. W.Sh. Stump's Wood, Malverns; Walsall, &c.

22. RHYNCHONELLA? (ATRYPA) COMPRESSA, Sow. Woolhope Limestone. Woodside and Nash, Presteign.

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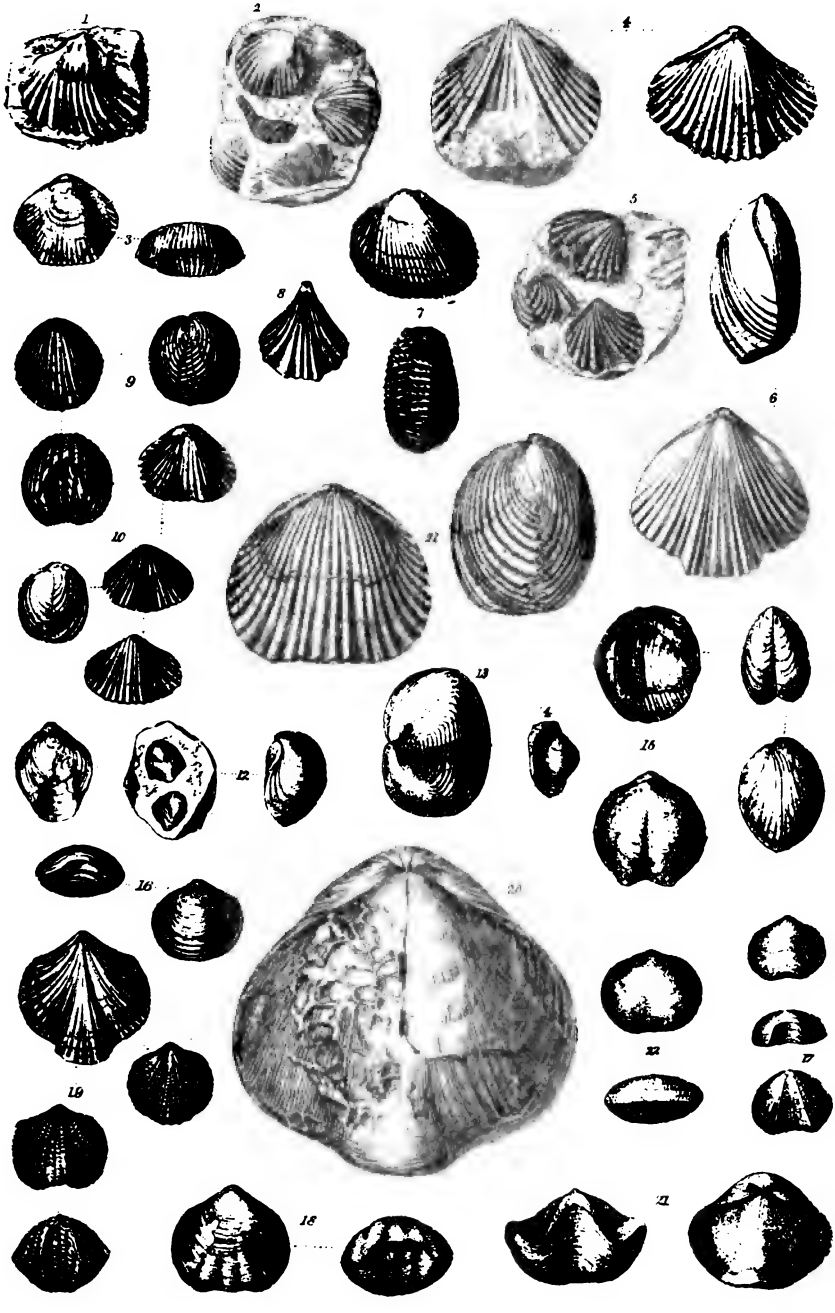
UPPER SILURIAN.

Pl 22.

BRACHIOPODA.



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Pl. 23.

LAMELLIBRANCHIATA

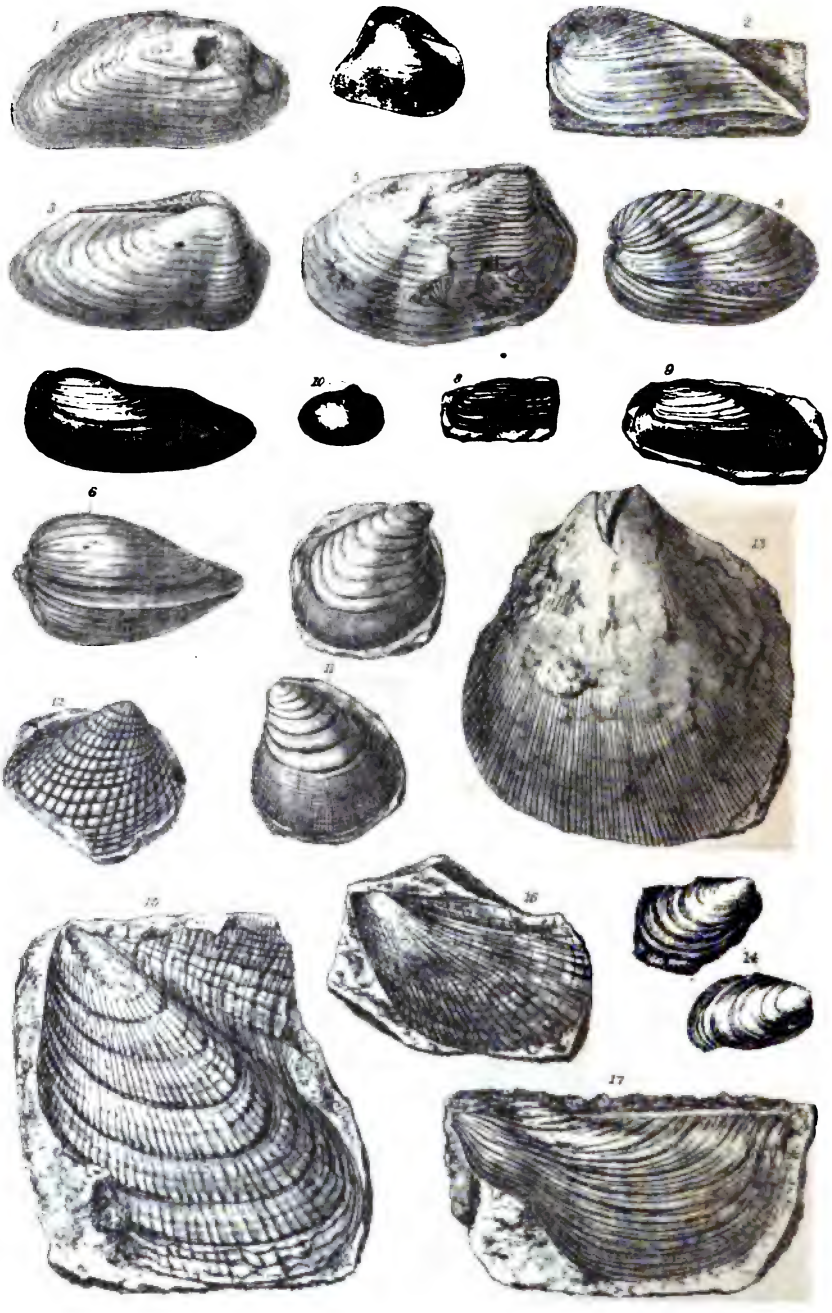

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PLATE XXIII.

UPPER SILURIAN LAMELLIBRANCHIATA.

Fig. 1. MODIOLOPSIS (PULLASTRA) COMPLANATA, Sow. U.L. Near Bridg-north.

2. GONIOPHORA (CYPRICARDIA) CYMBÆFORMIS, Sow. U.L. Ludlow.

3. ORTHONOTA (CYPRIC.) IMPRESSA, Sow. U.L. Delbury.

4. O. (CYPRIC.) UNDATA, Sow. U.L. Near Aymestry.

5. O. (MYA) ROTUNDATA, Sow. A.L. Caynham Camp, Ludlow.

6. O. (CYPRICARDIA) AMYGDALINA, Sow. U.L. Ludlow, &c.

7. ———. Variety. (C. RETUSA, Sow.) U.L. Delbury.

8. O. (PSAMMOBIA) RIGIDA, Sow. L.L. Garden House, Aymestry.

9. O. (CYPRICARDIA ?) SOLENOIDES, Sow. L.L. Near Ludlow.

10. CTENODONTA ANGLICA, d'Orb. (NUCULA OVALIS.) U.L. Trewerne Hills, Radnorshire.

11. CARDIOLA FIBROSA, Sow. L.L. Mary Knoll Dingle, Ludlow.

12. C. INTERRUPTA, Broderip. L.L. Aymestry, Radnorshire, &c.

13. C. (CARDIUM) STRIATA, Sow. A.L. Aymestry.

14. MODIOLA ANTIQUA, Sow. W.Sh. Glass House Hill, E. of May Hill, Gloucestershire.

15. PTERINEA SOWERBYI, M'Coy. (AVICULA RETICULATA.) A.L. Croft, Aymestry.

16. PT. LINEATULA, d'Orb. (AVICULA LINEATA.) U.L. Ludlow.

17. PT. (AVIC.) RETROFLEXA, Wahl. U.L. Malverns.

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PLATE XXIV.

UPPER SILURIAN GASTEROPODA.

Fig. 1. TURBO CORALLII, Sow. U.L. Radnorshire.

2. MURCHISONIA (PLEUROTOMA) ARTICULATA, Sow. U.L. Ludlow.

3. LOXONEMA SINUOSA, Sow. L.L. Aymestry.

4. TURBO OCTAVIUS, d'Orb. (CARINATUS.) U.L. Trewerne Hills, Radnorshire.

5. MURCHISONIA (PLEUROTOMARIA) LLOYDII, Sow. L.L. Shelderton; Aymestry.

6. PLEUROTOMARIA UNDATA, Sow. L.L. Near Ludlow.

7. MURCHISONIA (PLEUROTOMA) CORALLII, Sow. U.L. Bradnor Hill, Kington.

8. ACROCULIA PROTOTYPA, Phill. (NERITA SPIRATA.) Woolhope Limestone, Presteign.

9. A. (NERITA) HALIOTIS, Sow. W.L. Ledbury.

10. TURBO CIRRHOSUS, Sow. W.Sh. Wenlock.

11. EUOMPHALUS CARINATUS, Sow. A.L. Aymestry.

12. E. DISCORS, Sow. W.L. Wenlock Edge.

13. E. RUGOSUS, Sow. W.L. Wenlock Edge.

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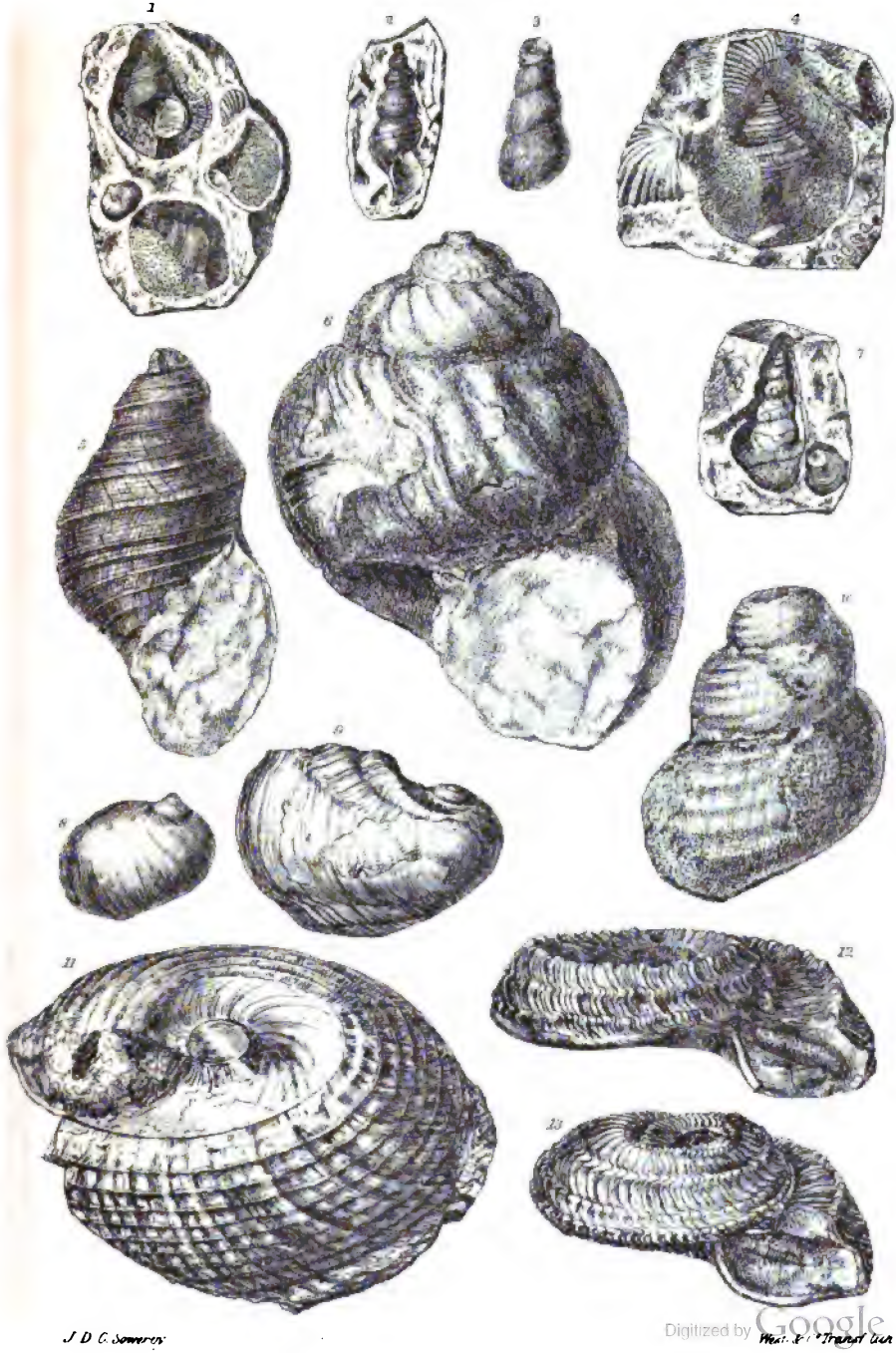
UPPER SILURIAN.

Pl 24.

GASTEROPODA.



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UPPER SILURIAN.

Pl 25

GASTEROPODA. &c.

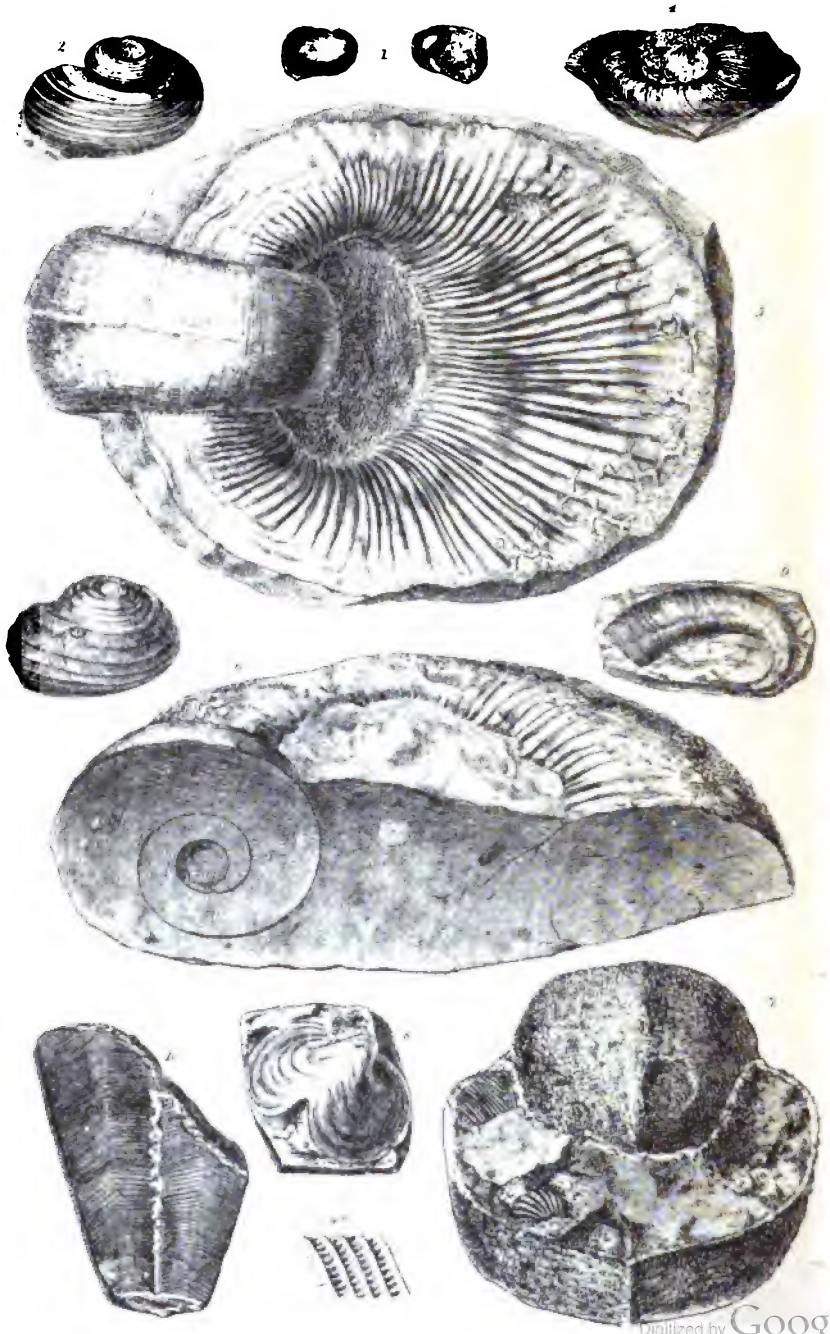

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PLATE XXV.

UPPER SILURIAN GASTEROPODA, PTEROPODA, AND HETEROPODA.

Fig. 1. NATICA PARVA, Sow. U.L. Fownhope, Herefordshire.

2. EUOMPHALUS SCULPTUS, Sow. W.L. Ledbury.

3. E. FUNATUS, Sow. W.L. Wenlock Edge.

4. E. ALATUS, Wahl. W.Sh. Delves Green; Tame Bridge.

5, 6. BELLEROPHON DILATATUS, Sow. W.Sh. Burrington, Ludlow.

7. B. WENLOCKENSIS, Sow. W.Sh. Croft, Malvern.

8. B. EXPANSUS, Sow. U.L. Ludlow.

9. CYRTOLITES? (CYRTOCERAS) LÆVIS. L.L. Abberley.

10. CONULARIA SOWERBYI, Defrance. (QUADRISULCATA.) W.L. Wenlock Edge.

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PLATE XXVI.

UPPER SILURIAN CEPHALOPODA.

Fig. 1. ORTHOCERAS ANNULATUM, Sow. W.L. Hay Head, Walsall.

2. ———, var. FIMBRIATUM. (O. FIMBRIATUM, Sow.) W.Sh. Aston, May Hill; Malverns, &c.

3. O. ATTENUATUM, Sow. W.Sh. Onny River, Shropshire.

4. O. DISTANS, Sow. L.L. Near Aymestry.

5. O. NUMMULARIUM, Sow. W.Sh. Whitfield Quarry, Tortworth.

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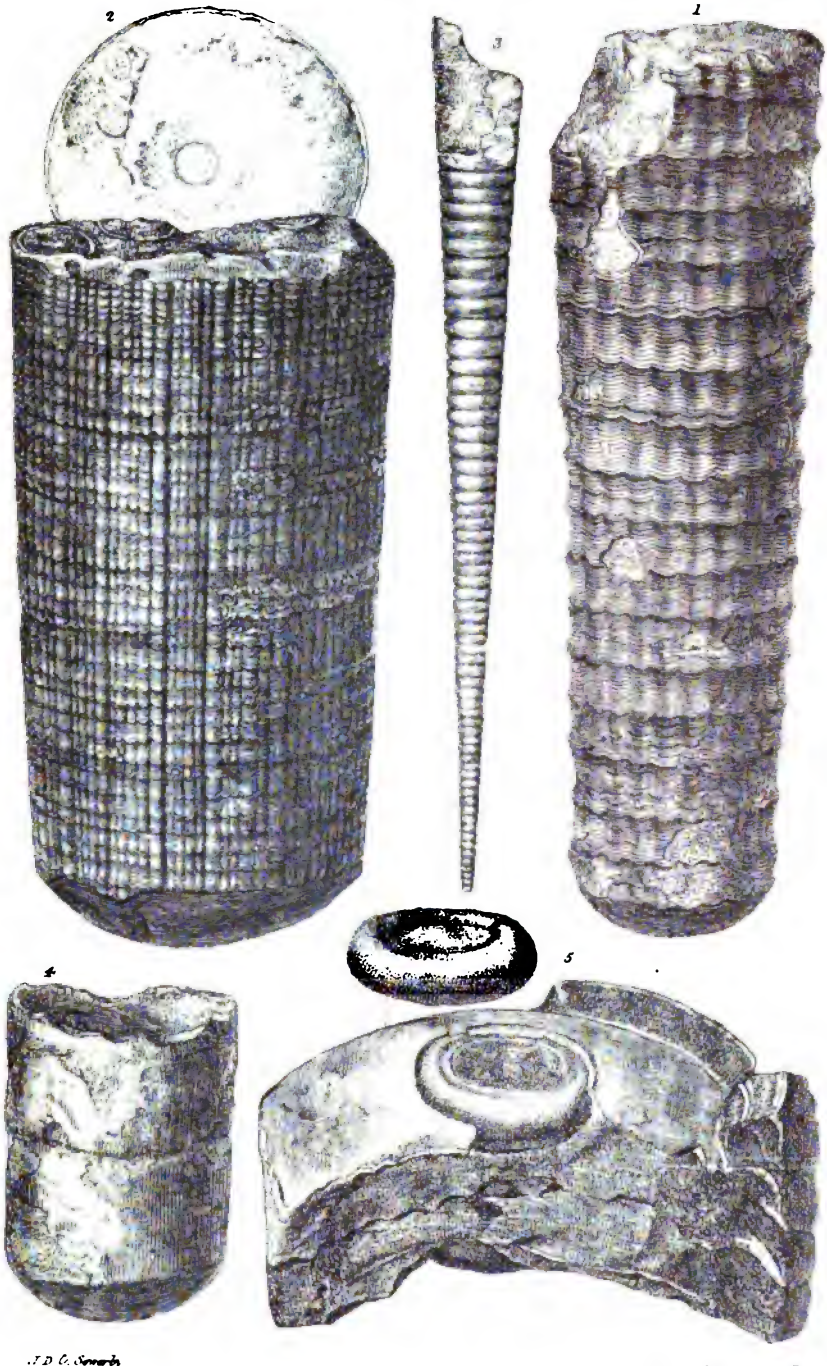
UPPER SILURIAN.

CEPHALOPODA.

Pl. 26.



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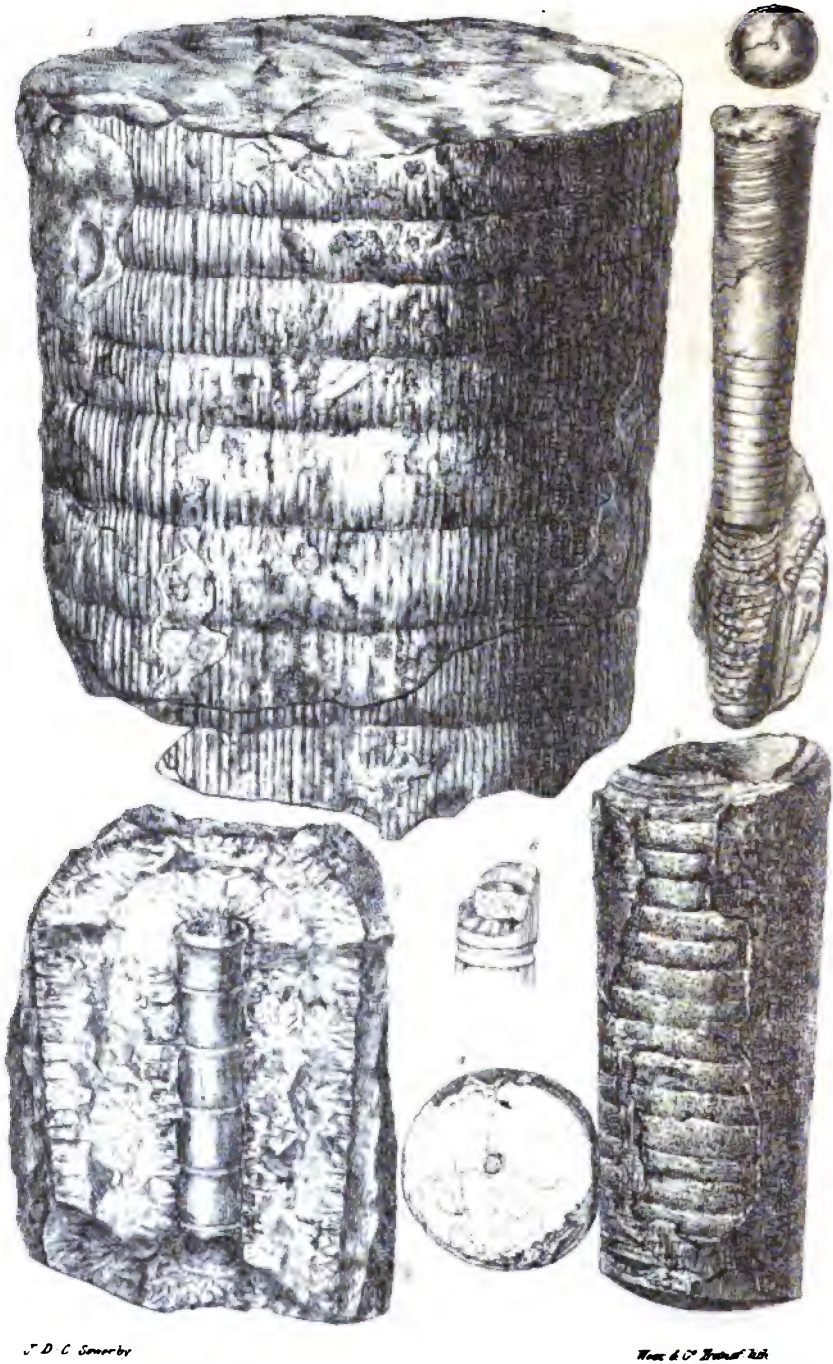
UPPER SILURIAN.

CEPHALOPODA.

Pl. 27.



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Wood & Co. Bristol lith.

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PLATE XXVII.

UPPER SILURIAN CEPHALOPODA.

Fig. 1. ORTHOCERAS FILOSUM, Sow. L.L. Leintwardine.

2. O. GREGARIUM, Sow. L.L. Near Ludlow.

3, 4. O. EXCENTRICUM, Sow. Woolhope Limestone, Old Radnorshire.

5. ORMOCERAS (ORTHOCERAS) BRIGHTII, Sow. Broken open. W.L. Malverns.

6. ————. The siphuncle, slightly magnified.

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PLATE XXVIII.

UPPER SILURIAN CEPHALOPODA.

Fig. 1, 2. ORTHOCERAS LUDENSE, Sow. L.L. Ludlow.

3. O. CANALICULATUM, Sow. W.Sh. Ledbury.

4. O. ANGULATUM, Hisinger. (VIRGATUM.) L.L. Mocktree Forest.

5. O. DIMIDIATUM, Sow. L.L. Water-break-its-neck, Radnor Forest.

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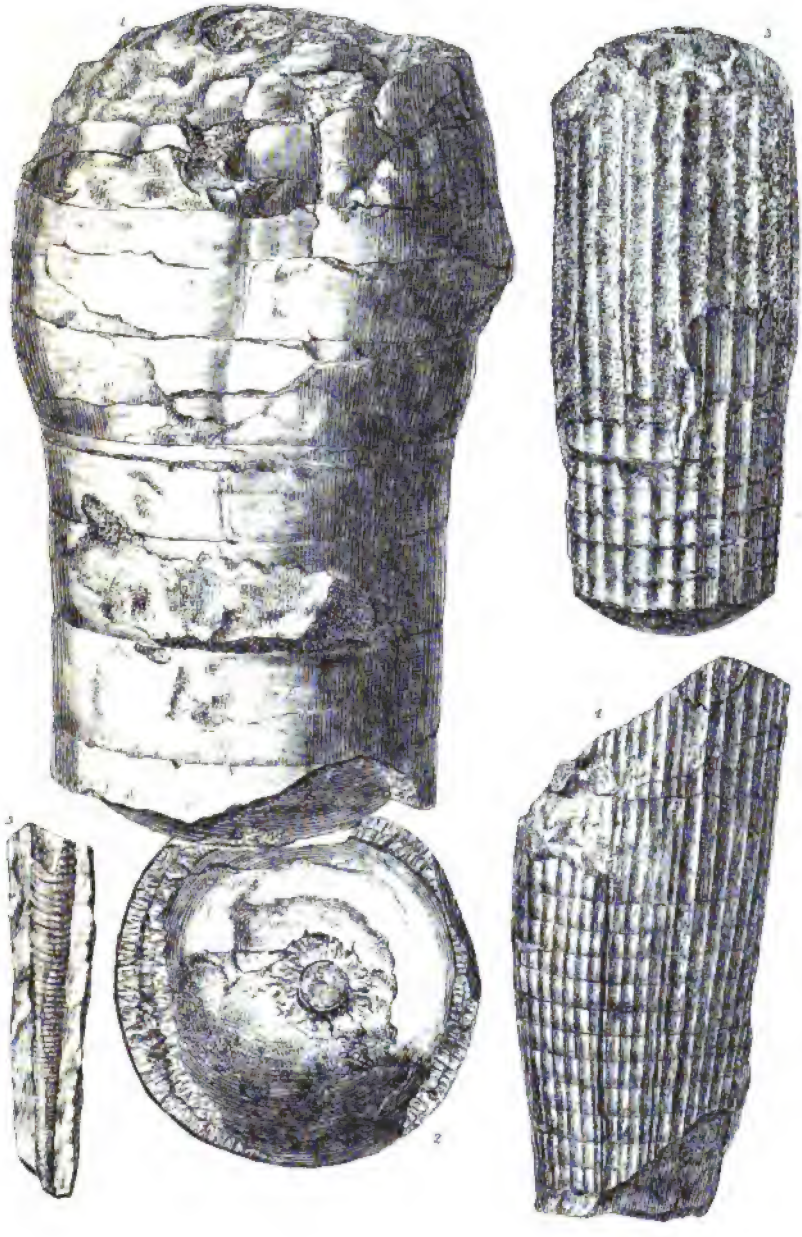
UPPER SILURIAN.

Pl. 28.

CEPHALOPODA.



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West & Co. Transf. lith.

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UPPER SILURIAN.

CEPHALOPODA.

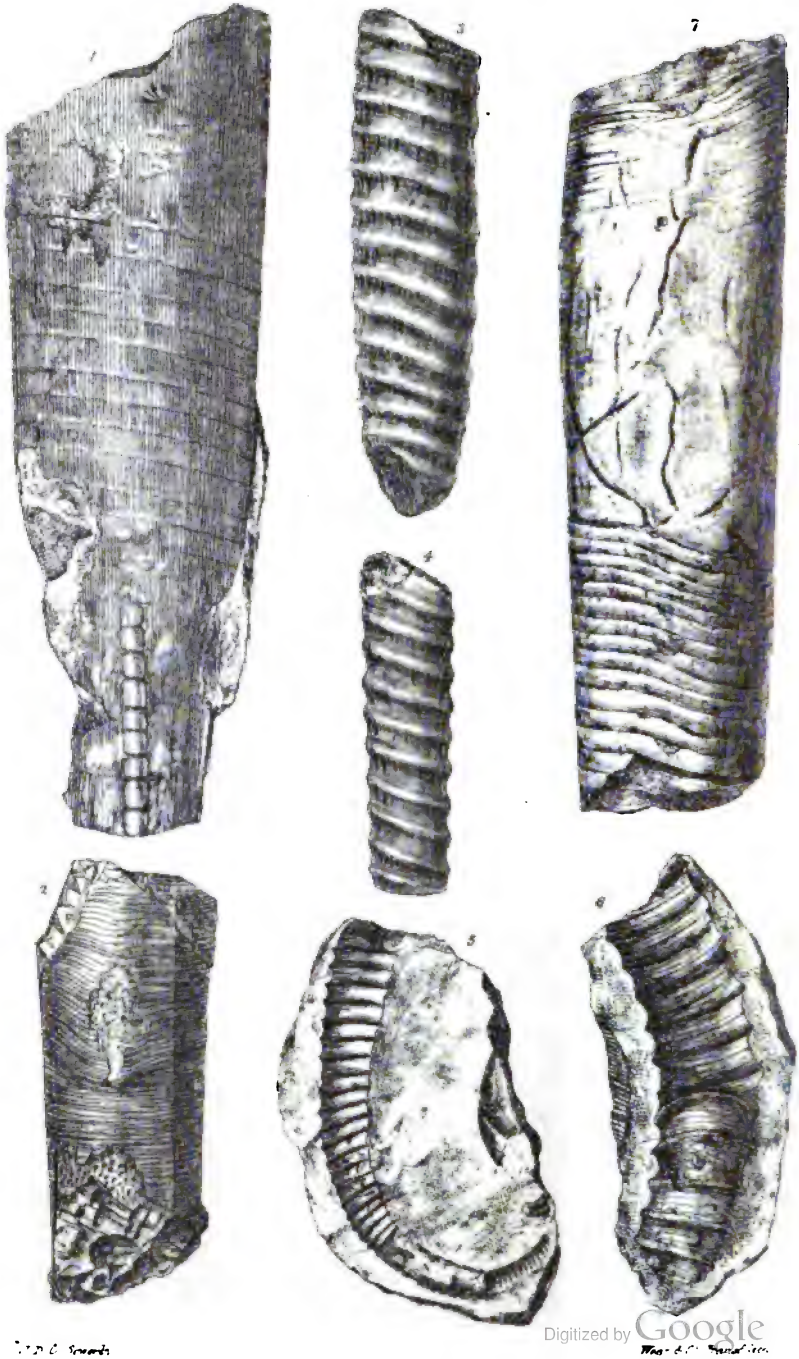

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PLATE XXIX.

UPPER SILURIAN CEPHALOPODA.

Fig. 1. ORTHOCERAS BULLATUM (or STRIATUM), Sow. U.L. Ludlow.

2. O. MOCKTREENSE, Sow. A.L. Mocktree Hays, Shropshire.

3, 4. O. IBEX, Sow. (including O. ARTICULATUM). U.L. Near Ludlow.

5, 6. O. PERELEGANS, Salter. (LITUITES IBEX and L. ARTICULATUS.) L.L. Elton, Fig. 5; Shelderton, Fig. 6.

7. O. IMBRICATUM, Wahl. L.L. Near Ludlow.

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PLATE XXX.

UPPER SILURIAN CEPHALOPODA.

Fig. 1, 2, 3. PHRAGMOCERAS (ORTHOCERAS or GOMPHOCERAS) PYRIFORME. Sow. L.L. Leintwardine.

4. P. INTERMEDIUM, M'Coy. (ARCUATUM, var. β.) L.L. Shelderton.

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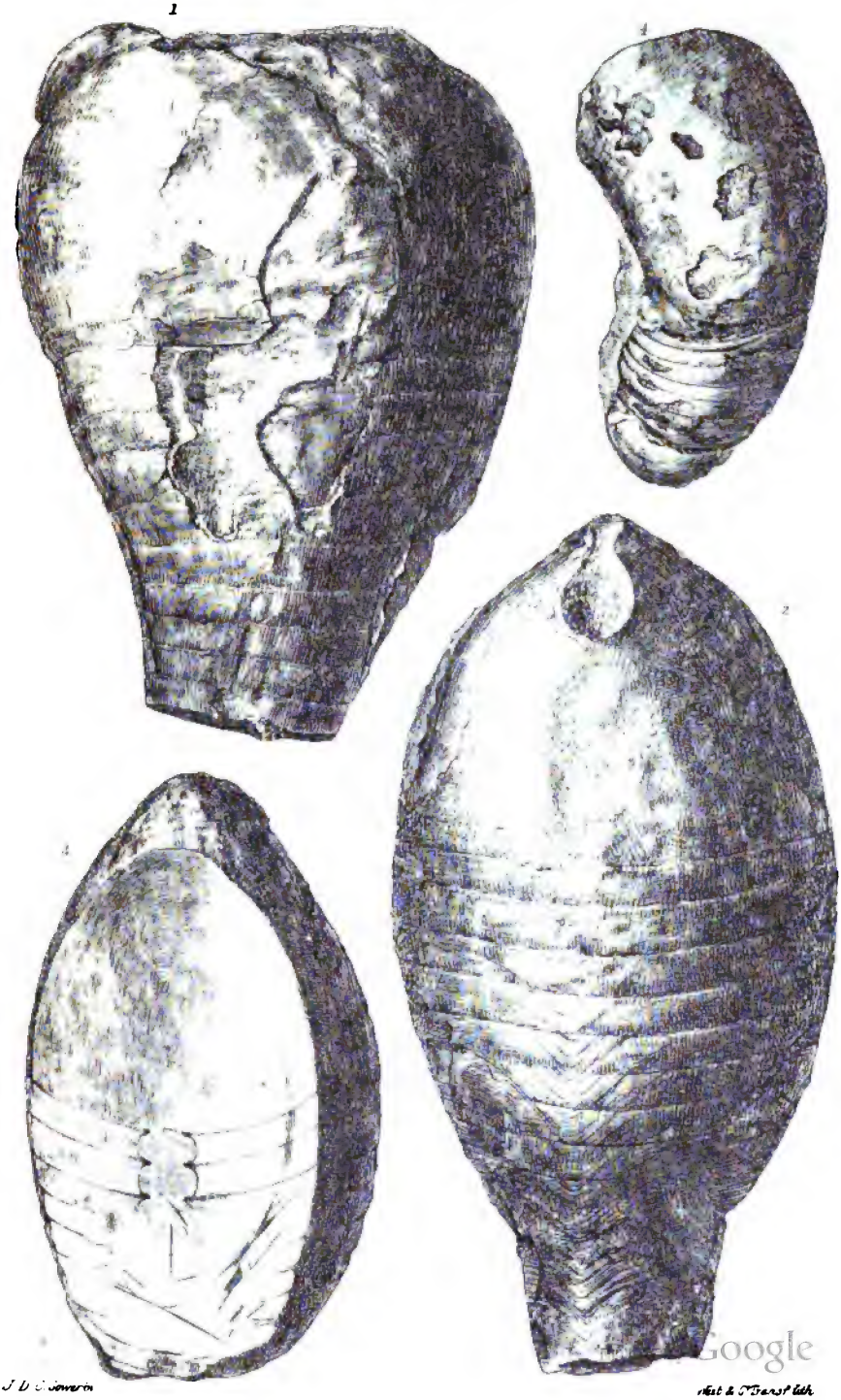
UPPER SILURIAN.

CEPHALOPODA.



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UPPER SILURIAN.

CEPHALOPODA.

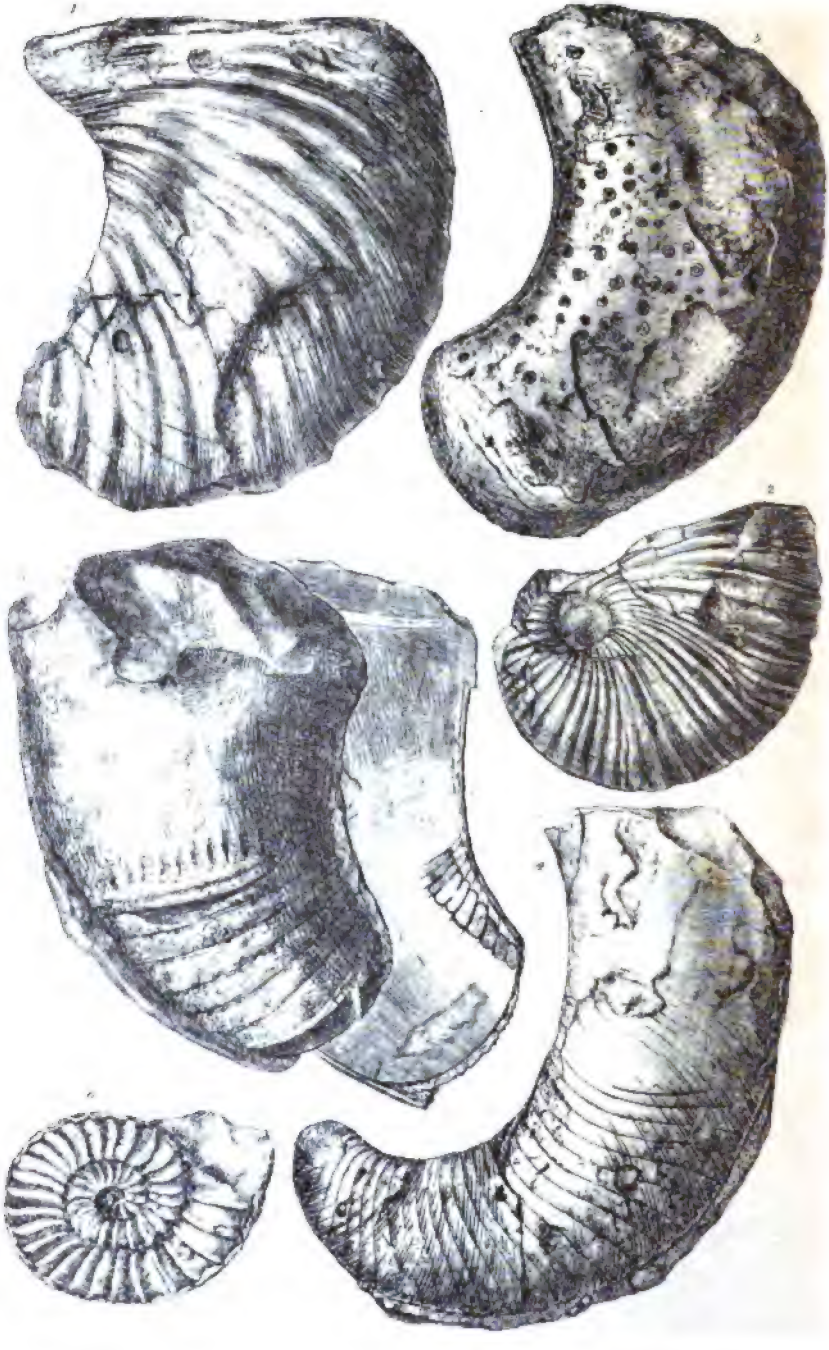

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PLATE XXXI.

UPPER SILURIAN CEPHALOPODA.

Fig. 1, 2. PHRAGMOCERAS NAUTILEUM, Sow. W.S. Myddelton Hall, Caermarthen.

3. P. ARCUATUM, Sow. L.L. Near Ledbury.

4. P. COMPRESSUM, Sow. L.L. Near Aymestry.

5. LITUITES BIDDULPHII, Sow. (Numerous specimens of the minute SPIRORBIS LEWISII are imbedded in the cast, having been detached from the inner surface of the Lituite, where they had taken up their residence after the cephalopod had quitted it.) W.L. Ledbury.

6. L. ARTICULATUS, Sow. L.L. Near Ludlow.

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PLATE XXXII.

UPPER SILURIAN CEPHALOPOD.

Fig. 1, 2. PHRAGMOCERAS VENTRICOSUM, Sow. L.L. Leintwardine.

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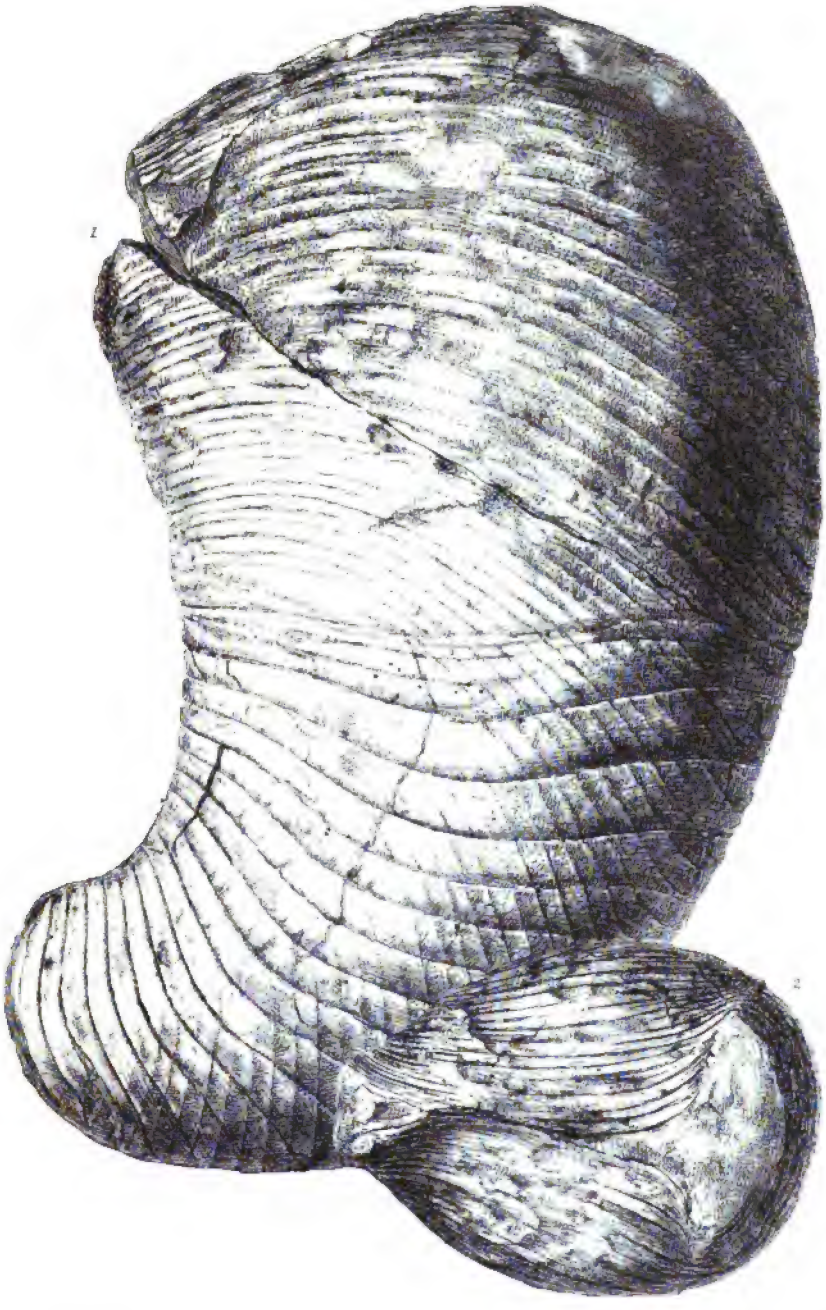
OPPER SILURIAN.

Pl. 32.

CEPHALOPODA.



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UPPER SILURIAN.

CEPHALOPODA

Pl 33.

J. D. C. Sowerby.

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PLATE XXXIII.

UPPER SILURIAN CEPHALOPODA.

Fig. 1, 2, 3. LITUITES GIGANTEUS, Sow. L.L. Mocktree Hays.

4. LITUITES ? TORTUOSUS, Sow. L.L.? Between Welshpool and Berriew, Montgomeryshire.

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PLATE XXXIV.

FOSSILS, CHIEFLY MOLLUSCS, OF THE UPPER LUDLOW ROCK.

[Mostly from the "Tilestone-beds" of South Wales.]

Fig. 1. ONCHUS MURCHISONI, Agassiz. A true fish-defence. Tin Mill, Downton, Ludlow. In the Downton Sandstone.

2. LINGULA CORNEA, Sow. Tin Mill, Downton. Downton Sandstone.

3. CUCULLELLA CAWDORI, Sow. In Upper? Ludlow Rock. Freshwater East, Pembrokeshire.

4. PTERINEA (AVICULA) RECTANGULARIS, Sow. Horeb Chapel, Llandovery.

5. ORTHOCERAS? SEMIPARTITUM, Sow. Horeb Chapel.

6. O. TRACHEALE, Sow. Horeb Chapel, Llandovery.

7. MODIOLOPSIS (PULLASTRA) LÆVIS, Sow. Horeb Chapel.

8. BELLEROPHON CARINATUS, Sow. Horeb Chapel.

9. B. TRILOBATUS, Sow. Felindre, ten miles W. of Knighton.

10. HOLOPELLA (TURRITELLA) CONICA, Sow. Horeb Chapel.

10*a*. H. (TURRITELLA) GREGARIA, Sow. Horeb Chapel.

11. H. (TURRITELLA) OBSOLETA, Sow. Horeb Chapel; Felindre.

12, 13. TROCHUS? HELICITES, Sow. Horeb Chapel.

14. TURBO WILLIAMSI, Sow. Horeb Chapel.

15. GONIOPHORA (CYPRICARDIA) CYMBÆFORMIS, Sow. Felindre.

16. CUCULLELLA (CUCULLÆA) ANTIQUA, Sow. Horeb Chapel.

17. C. (CUCULLÆA) OVATA, Sow. Horeb Chapel.

18. CHONETES (LEPTÆNA) LATA, von Buch. Horeb Chapel.

19. BELLEROPHON MURCHISONI, d'Orbigny? (STRIATUS.) Felindre.

20. B. EXPANSUS, Sow. Young. (GLOBATUS.) Felindre.

21. BEYRICHIA KLŒDENI, M'Coy? (AGNOSTUS TUBERCULATUS.) Lodge Bank, Downton.

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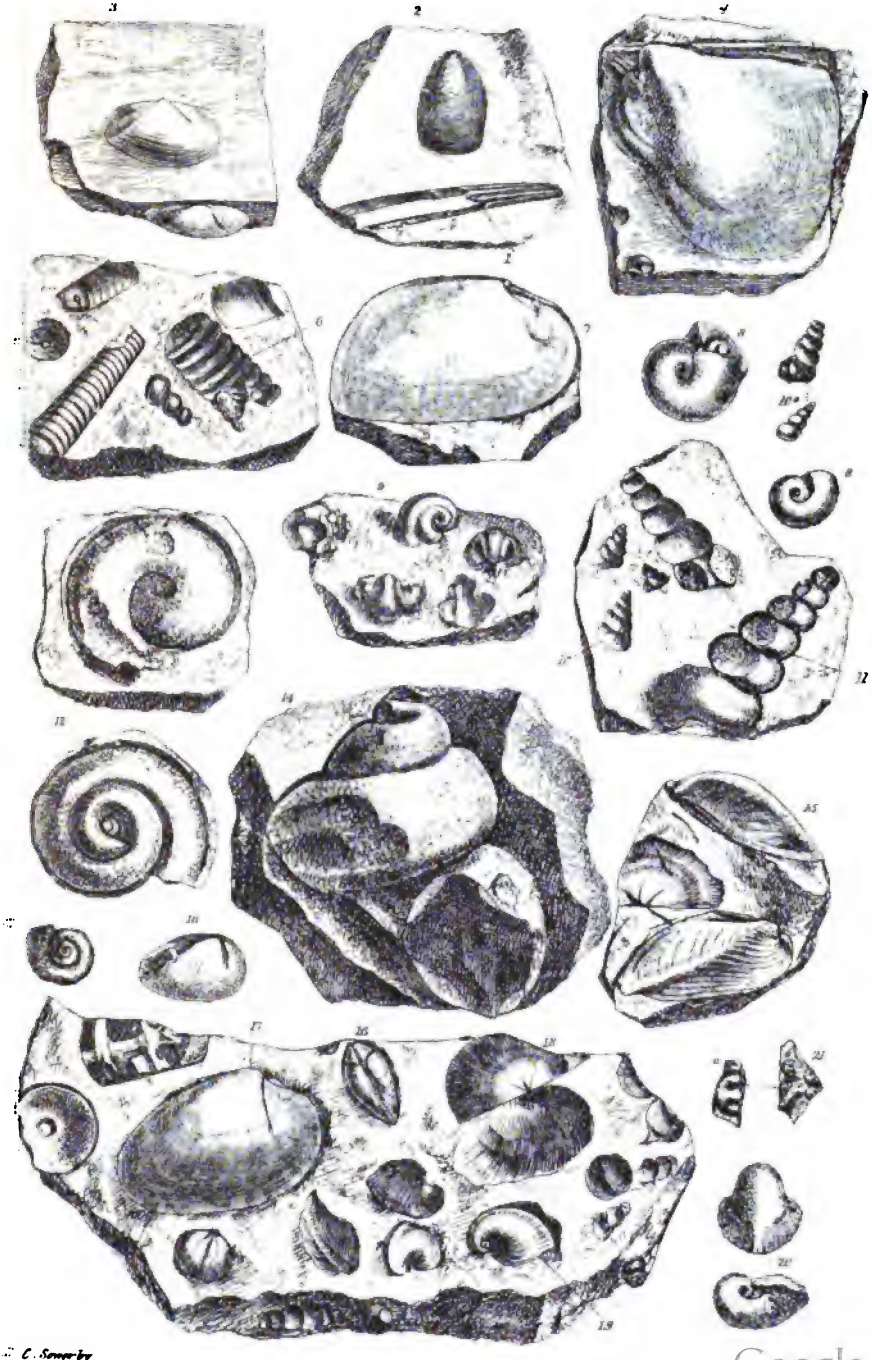
UPPER LUDLOW ROCK.

Pl. 34.



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UPPER LUDLOW ROCK.

Pl. 35.

BONE BED.

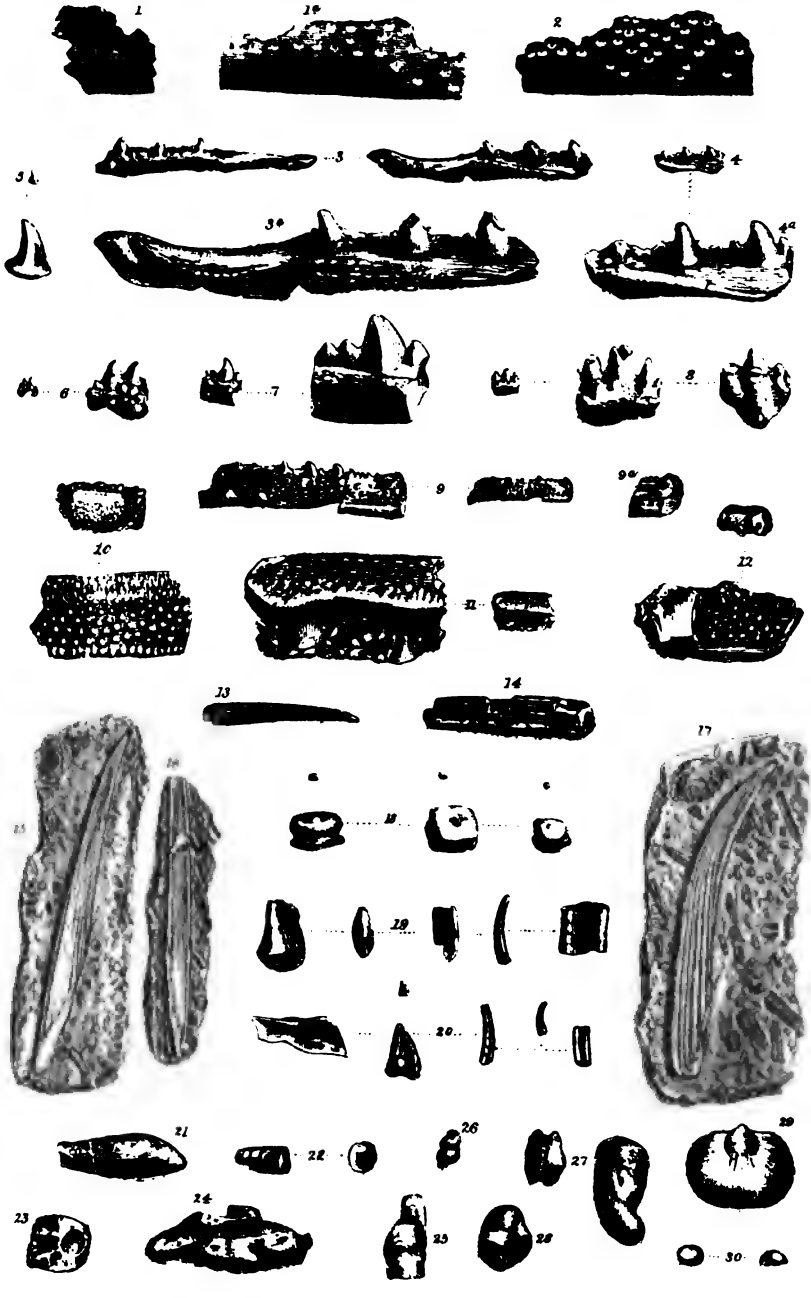

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PLATE XXXV.

FOSSILS, CHIEFLY FISH-REMAINS, OF THE UPPER LUDLOW BONE-BED.

[All these are from Ludford, near Ludlow.]

Fig. 1, 2. SPHAGODUS, Agass. (S. PRISTODONTUS.) Skin: 1*a* and 2, magnified portions.

3–8. PLECTRODUS MIRABILIS, Agass. Jaws and teeth, natural size and magnified.

9–12. P. (SCLERODUS) PUSTULIFERUS, Agass. Natural size, and magnified.

13, 14. ONCHUS MURCHISONI, Agass. Fish-defence; the most common species.

15–17. O. TENUISTRIATUS, Agass. Fish-defence.

18. SHAGREEN SCALES, probably of ONCHUS TENUISTRIATUS, according to M'Coy. (THELODUS PARVIDENS, Ag.) These are very abundant.

19, 20. Indeterminable fragments.

21–28. COPROLITES (probably of PLECTRODUS, Agass.), and containing — ORTHOCERAS SEMIPARTITUM, Fig. 22; ENCRINITE STEMS, 23, 24; LINGULA CORNEA, 25; HOLOPELLA CONICA, 26; ORBICULA RUGATA, 27; BELLEROPHON EXPANSUS, 28. All fossils of the Upper Ludlow Rock.

29. ORTHIS LUNATA, Sow. Frequent in this bed.

30. SEEDS or SPORES of some Cryptogamic land-plant. (Dr. Hooker.)

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PLATE XXXVI.

FISHES OF THE OLD RED SANDSTONE.

Fig. 1–3. CEPHALASPIS LYELLII, Agass. Forfarshire.

4. ————. Side view of the head.

5. - - - - - . Exterior plates or scales of the head, highly magnified.

6. — — — — . Scales from the sides of the body, magnified.

7. ————. Scales from the flank.

8. ————. Scales from the sides of the tail.

9. PTERASPIS (CEPHALASPIS) LEWISII, Agass. Whitbatch, Shropshire.

10. P. (CEPHALASPIS) LLOYDII, Agass. Herefordshire.

10*. ————. A portion of the surface, and the texture of the under layer, magnified.

11. PTERASPIS (CEPHALASPIS) ROSTRATUS, Agass. Head, with the outer surface removed. Whitbatch, Shropshire.

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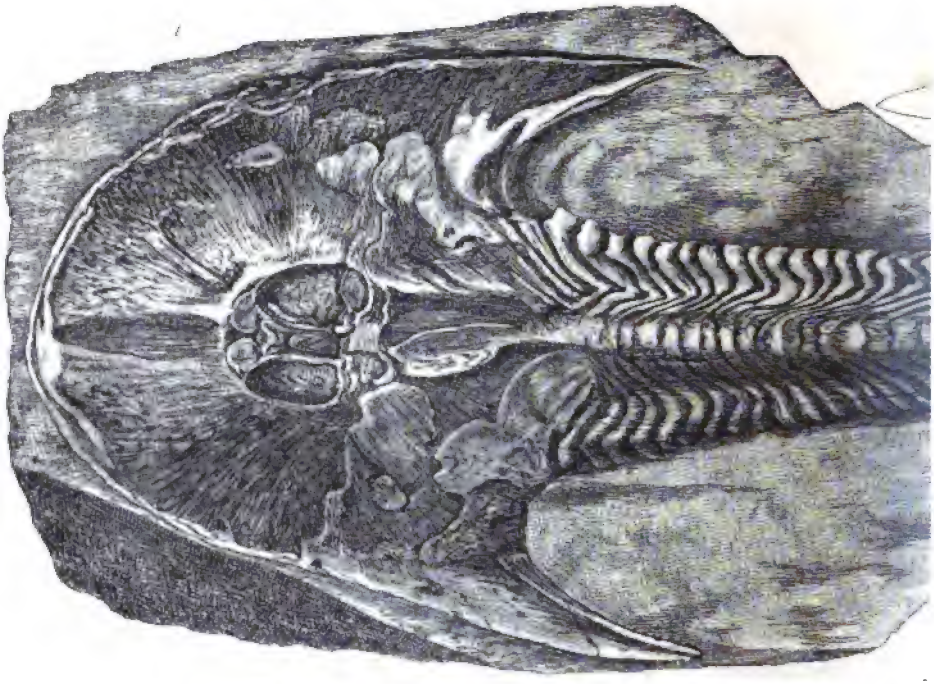

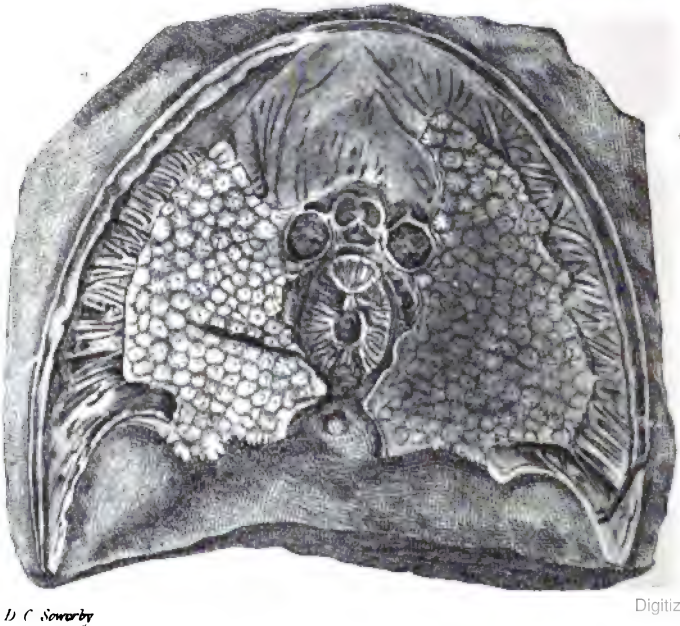

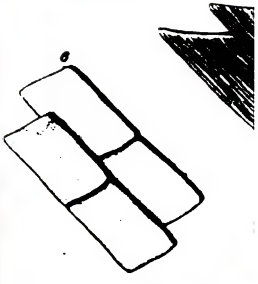

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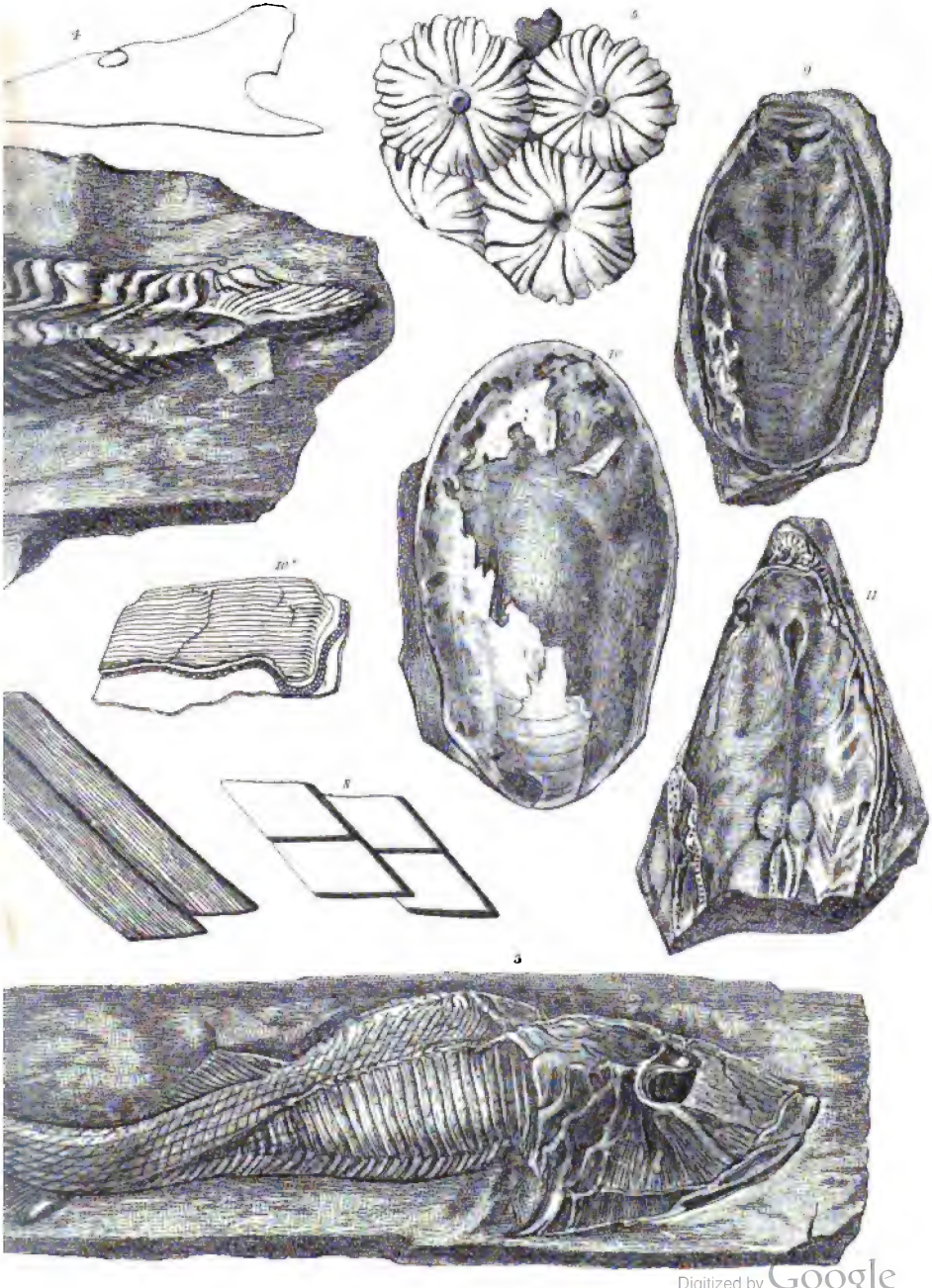

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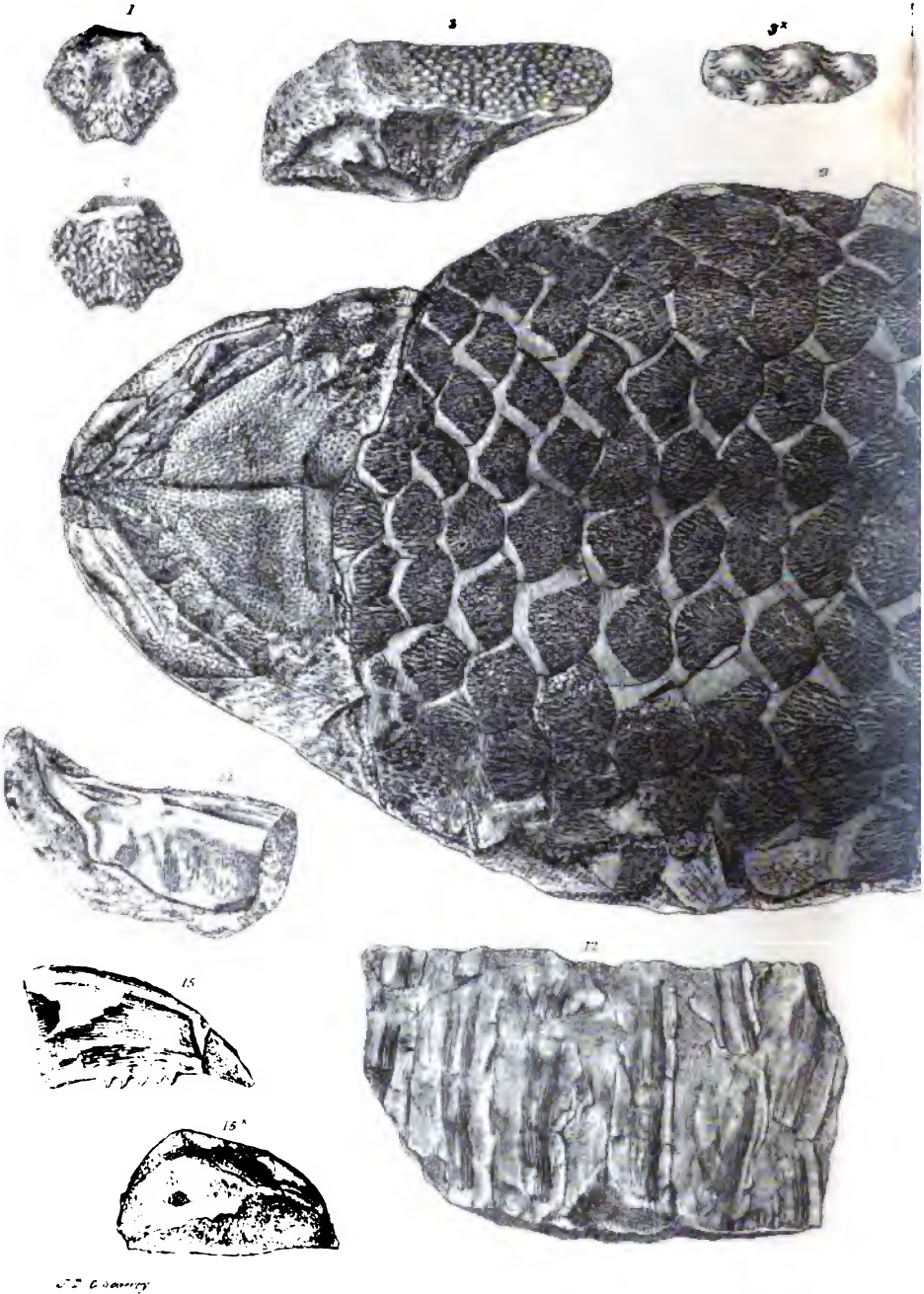

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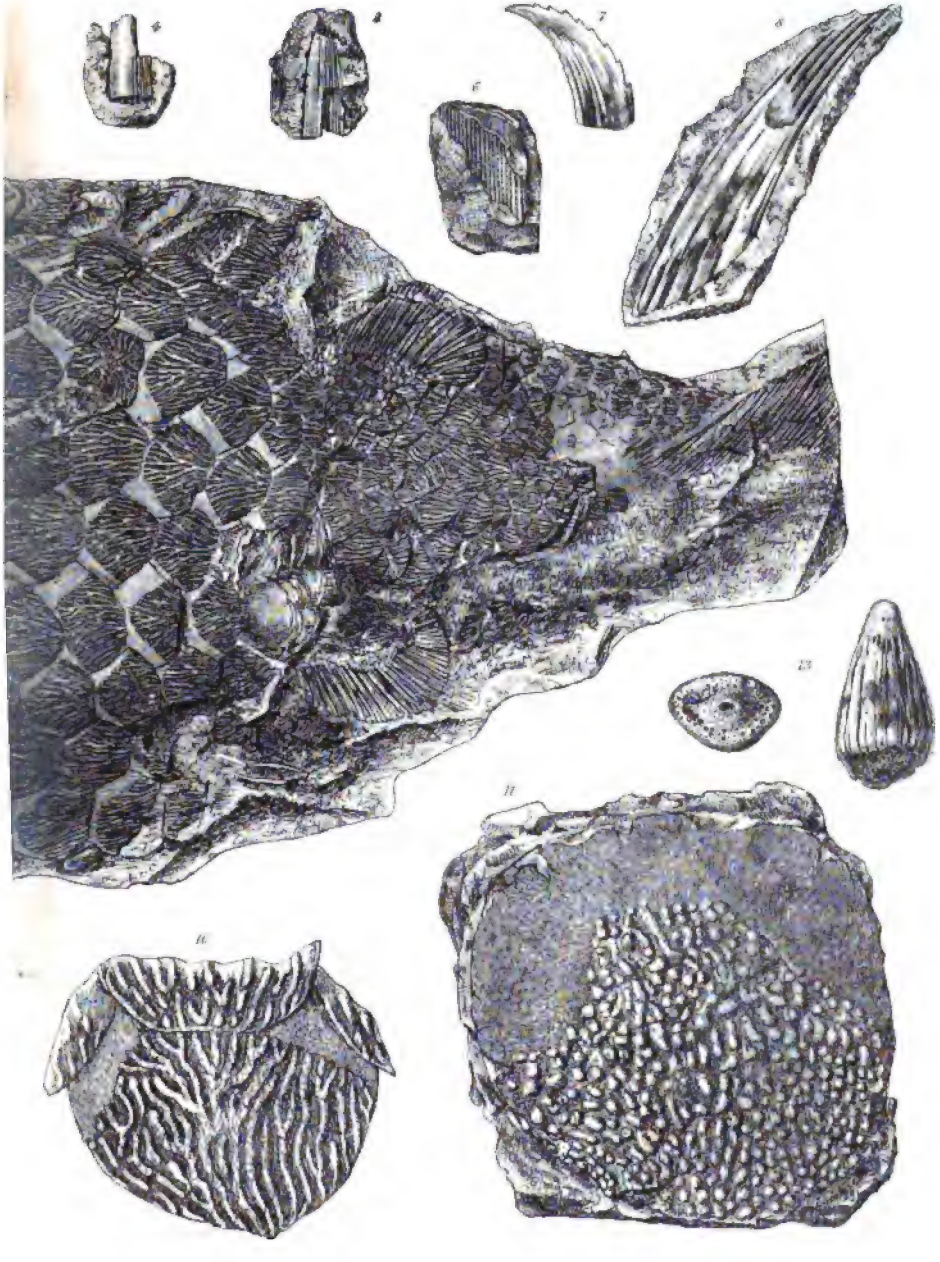

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PLATE XXXVII.

FISHES OF THE OLD RED SANDSTONE.

Fig. 1, 2. ASTEROLEPIS. Interior and exterior view of a bony plate from the head. Elgin.

3. ————. Bony armour of the head; 3*, a portion magnified.

4, 5. ONCHUS SEMISTRIATUS, Agass. Portions of Fish-defences. Tenbury.

6. CTENACANTHUS ORNATUS, Agass. Middle portion of a dorsal spine. Sapey, W. of Worcester.

7, 8. ONCHUS ARCUATUS, Agass. Fish-defence? Bromyard.

9. HOLOPTYCHIUS NOBILISSIMUS, Agass. One-third of the natural length. Clashbinnie, Perthshire.

10. ————. Ventral scales. Natural size.

11. H. GIGANTEUS, Agass. Scale. Clashbinnie.

12. H. NOBILISSIMUS, under side of the scales of.

13. HOLOPTYCHIUS, tooth of. Elgin.

14. Dorsal plate of COCCOSTEUS (CEPHALASPIS in the 'Sil. Syst.'). Herefordshire.

15. PTYCHACANTHUS? DUBIUS, Agass. Probably the serrated posterior spine of CEPHALASPIS. Magnified: 15*, natural size. Herefordshire.

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[The four following Plates of the SILURIAN CORALS and BRYOZOANS are reprinted from the lithographic stones used in the 'Silurian System.' See *Note*, p. 16**.]

PLATE XXXVIII.

(Pl. 16 *bis* 'Sil. Syst.')

Fig. 1. CYSTIPHYLLUM SILURIENSE, Lonsd. W.L. Wenlock and Dudley. 1*a*. Vertical section of ditto.

2. OMPHYMA MURCHISONI, Edw. and Haime. (CYSTIPHYLLUM SILURIENSE, in part.) W.L. Wenlock.

3. CYSTIPHYLLUM CYLINDRICUM, Lonsd. W.L. Benthall Edge. 3*a*. Vertical section. 3*b*. Calyx.

4. PTYCHOPHYLLUM PATELLATUM, Schloth. (STROMBODES PLICATUM.) Woolhope and Wenlock L. West side of Malverns. 4*a*. Vertical section. 4*b*. Cup of younger specimen. 4*c*. Lateral view of ditto.

5. PETRAIA BINA, Lonsd. Internal casts in Llandovery rock, Marloes Bay; also in the Wenlock, Aymestry, and Ludlow rocks. A common species.

6. P. ELONGATA, Phillips. Internal cast in Upper Llandovery rock, Lickey, Worcestershire. 6*a*. View of the base of the cast, showing the arched lamellæ.

7. CŒNITES JUNIPERINUS, Eichw. (LIMARIA CLATHRATA.) W.L. Dudley; Wenlock Edge; Woolhope, &c. 7*a*, 7*b*. Slightly enlarged, to show the linear mouths.

8. CŒNITES INTERTEXTUS, Eichw. (LIMARIA FRUTICOSA.) W.L. Wenlock and Dudley; Woolhope Limestone, Presteign. 8*a*. Magnified portion.

9. CYATHOPHYLLUM ARTICULATUM, Linn. A worn specimen. (CLADOCORA SULCATA.) W.L. Benthall Edge. 9*a*, 9*b*. Transverse sections of young and old stems.

10. VERTICILLOPORA? ABNORMIS, Lonsd. Ludlow rocks of Pyrton Passage, Gloucestershire. 10*a*. Transverse section. 10*b*. Pores, magnified. 10*c*. Lobed and branched specimen, showing the concentric coats and hollow centre. 10*d*. Vermicular pores, magnified.

11. CNEMIDIUM TENUE, Lonsd. W.L. Dudley. 11*a*. Central cavity and horizontal tubes. 11*b*. Surface-pores, magnified.

12. HELIOLITES INORDINATUS, Lonsd. (PORITES). Caradoc strata (Llandeilo flags, 'Sil. Syst.') of Robeston Wathen, Pembrokeshire. 12*a*. Stars, magnified. 12*b*. Cast of the same, magnified. 12*c*. Transverse sections of the stems.

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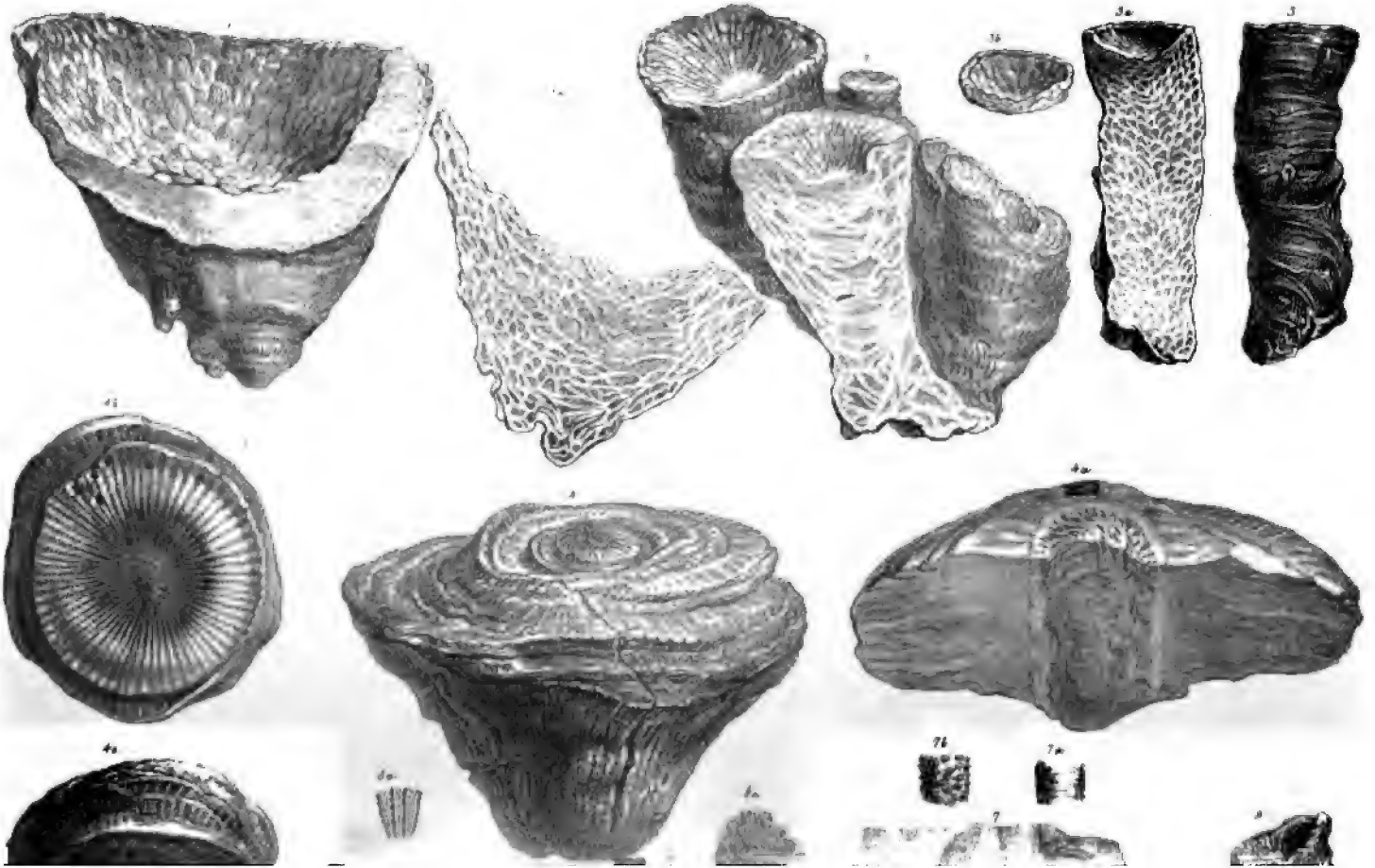

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Drawing from Nat. by C. Schaef

Printed by C. Hullmandel

1 1a. 2 Cystiphyllum Siluriense
3 3a. 3b Cystiphyllum cylindricum
5 5a Turbinolopsis bina
6 6a Turbinolopsis elongata
8 8a. Lunaria fractosa.
9 9a. 9b Cladocora sulcata
10 10a. to 10d. Verticillipora? obscura
11 11a. 11b Cremidium tenue
12 12a. to 12c. Porites? inordinata

PT 15

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PLATE XXXIX.

(Pl. 16 'Sil. Syst.')

Fig. 1. HELIOLITES? DISCOIDEUS, Lonsdale. (PORITES.) W.L. Wenlock.

2. H. INTERSTINCTUS, Linn. (PORITES PYRIFORMIS.) Caradoc rocks of Shropshire and Westmoreland, Wales, and Ireland. Llandovery rocks of Marloes Bay, Pembrokeshire, S. Wales, Ayrshire, Galway. Wenlock limestone and Ludlow rock of Wenlock, Dudley, Aymestry, &c. 2*a*. Surface magnified. 2*b*, 2*c*. Horizontal sections, nat. size and magnified. 2*d*. Shows the transverse lamellæ. 2*e*. A vertical section with these broken out or absent.

3. H. TUBULATUS, Lonsd. (PORITES.) Caradoc rocks of Montgomeryshire, and Llandovery rocks of Ayrshire and Wales (M'Coy). W.L. Dudley and Wenlock, May Hill, &c. 3*a*. Surface magnified twice. 3*b*. Vertical weathered surface. 3*c*, 3*d*, 3*e*. Transverse and vertical sections. 3*f*. Small variety, natural size.

4. H. PETALLIFORMIS, Lonsd. (PORITES.) W.L. and W.Sh. Dudley, Walsall. 4*a*. Horizontal section.

5. LABECHIA CONFERTA, Lonsd. (MONTICULARIA.) W.L. Benthall Edge, &c. 5*a*. Vertical section, weathered surface of ditto.

6. ACERVULARIA ANANAS, Linn. (ASTRÆA.) W.L. Dudley, Wenlock, Malverns, &c. 6*a*–6*f*. Young stars variously developed.

7. CYATHOPHYLLUM FLEXUOSUM, Lonsd. W.Sh. Malvern. 7*a*, 7*b*. Longitudinal and transverse sections.

8. ARACHNOPHYLLUM TYPUS, M'Coy. (ACERVULARIA BALTICA.) W.L. Wenlock and Dudley. Young specimen. 8*a*. Under surface of young specimen. 8*b*. Vertical section. 8*c*–8*e*. Older varieties; all nat. size.

9. CYATHOPHYLLUM ANGUSTUM, Lonsd. Llandovery (Upper). Coal Moors, Lickey, Worcestershire.

10. CYATH. ARTICULATUM, Wahl. (CÆSPITOSUM.) W.L. Wenlock, Dudley, &c. (One-third natural size.)

11. OMPHYMA TURBINATUM, Lonsd. (CYATHOPHYLLUM.) Llandovery rock, Prolimoor, and W.Sh., same locality. W.L. Wenlock, &c. 11*a*. Vertical section.

12. CYATHOPHYLLUM TRUNCATUM, Linn. (DIANTHUS.) W.L. Ledbury, Wenlock, &c. 12*b*, *c*. Vertical and transverse sections. 12*d*. A calyx with young corallites.

12*a*. ACERVULARIA ANANAS, Linn., var. RAMOSA, M'Coy. (CYATHOPHYLLUM DIANTHUS, in part.) This variety differs from the type (Fig. 6) by having the corallites separate from each other, and not pressed into an hexagonal form. 12*c*. is probably a single calyx with four young buds of the same variety; it has been referred to the C. ARTICULATUM by Milne-Edwards with doubt.

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PLATE XL.

(Pl. 15 *bis* 'Sil. Syst.')

Fig. 1. FAVOSITES ALVEOLARIS, Blainv. Caradoc sandstone to Aymestry rock. Everywhere in the Silurian System. 1*a*. Magnified tubes. 1*b*. shows the cross tabulæ.

2. ————. Larger variety of the same. 2*a*. Weathered tubes showing the tabulæ.

3. FAVOSITES GOTHLANDICA, Linn. Caradoc sandstone to Ludlow rock. Wales, Shropshire, Ireland, &c. 3*a*. Magnified tubes.

4. ————. Polished section, exhibiting one or more rows of foramina.

5. FAVOSITES MULTIPORA, Lonsd. Wenlock rocks, Marloes Bay. Under surface. 5*a*. Vertical section. 5*b*. Detached tubes. 5*c*. Upper surface weathered.

6. STENOPORA FIBROSA, Goldf. (FAVOSITES.) Llandeilo flags to Upper Ludlow rock. Everywhere in the Silurian region. 6. A vertical section. 6*a*. Tubes magnified, with transverse tabulæ. 6*b*. Transverse section.—6, 6*b*, *c*, *e*. are vertical and cross fractures of solid specimens. 6*a*. Magnified tubes, weathered, showing interior tabulæ. 6*d*, *f*. Tubes magnified, showing pores and marginal processes.

7. STENOPORA FIBROSA. A branched specimen.

8. ALVEOLITES LABECHII, Edw. and Haime. (FAVOSITES SPONGITES.) W.L. Benthall Edge; Woolhope, &c. 8*a*, *b*. Vertical section, nat. size and magnified. 8*c*. Vertical section, cylindrical variety. 8*d*, *e*. Surface magnified.

9. CHÆTETES (or NEBULIPORA) FLETCHERI, Edw. and Haime. (FAVOSITES SPONGITES, variety.) W.L. Dudley. 9*a*. Magnified. 9*b*. A branch, nat. size.

10. SYRINGOPORA BIFURCATA, Lonsd. (RETICULATA.) W.L. Gleedon Hill, Wenlock. 10*a*. The same magnified.

11, 11*a*. S. BIFURCATA, Lonsd. The basal prostrate portions of the same species. 11*b*. Tube magnified, showing section.

12. S. FASCICULARIS, Linn. (FILIFORMIS.) W.L. Eastnor Park, and Usk. Ludlow rock. Ristley Wood, Newent.

13. S.? CÆSPITOSA, Lonsd. W.L. Wenlock and Woolhope.

14. HALYSITES CATENULARIUS, Linn. (CATENIPORA ESCHAROIDES.) Caradoc sandstone to Ludlow rock. 14*a*. Cast of tubes. 14*b*. Ditto magnified.

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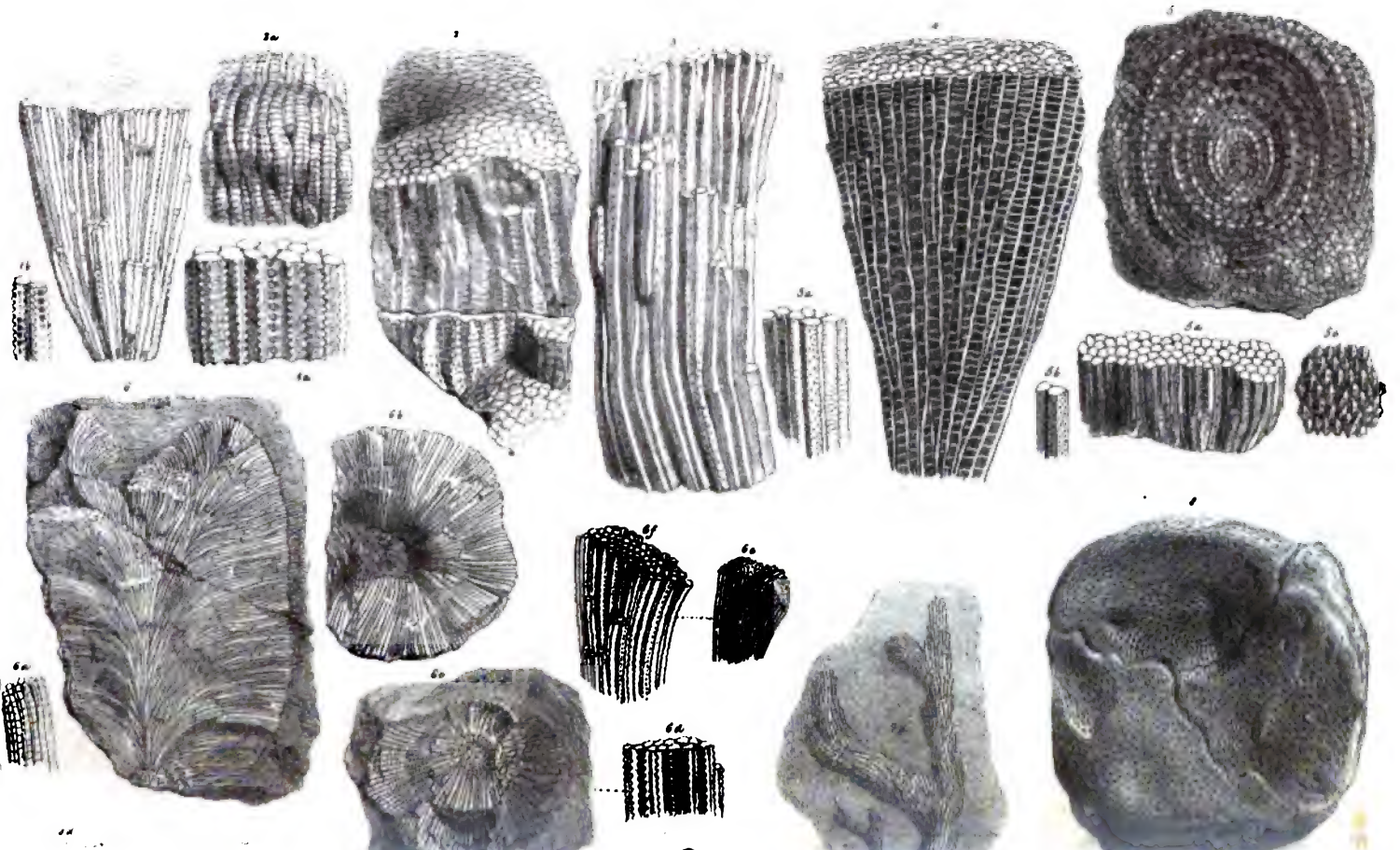
SILURIAN ROCKS.
(CORALS)



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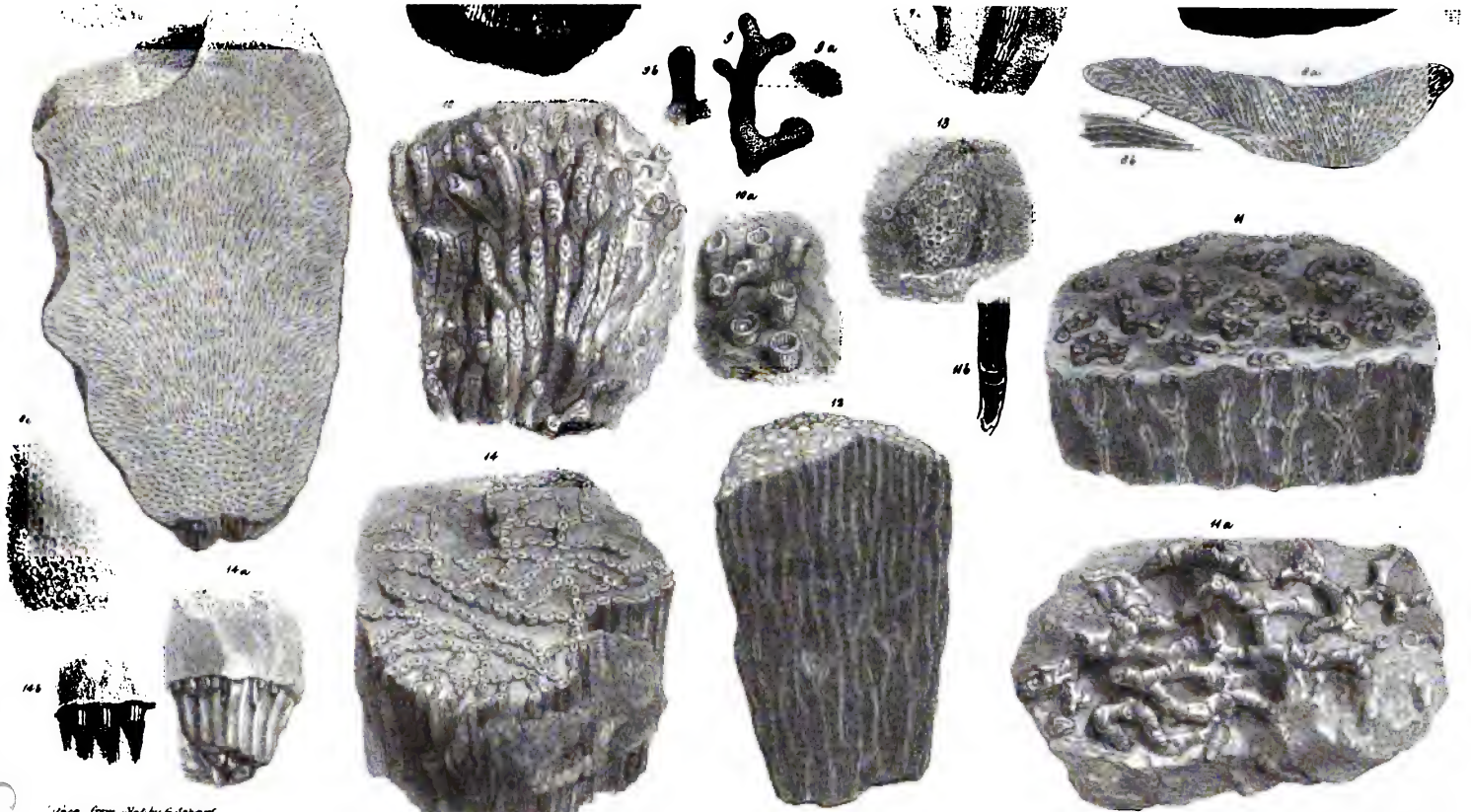

1 1a. 1b 2. 2a. Favosites alveolaris
3. 3a. 4. Favosites Gothlandica
5. 5a. 5b. Favosites multipora
6. 6a to 6f. Favosites fibrosa.
7. 7a. Favosites fibrosa.
8. 8a to 8e. Favosites spongites
9. 9a. 9b. Favosites spongites.
10. 10a. Syringopora reticulata.
11. 11a. 11b. Syringopora bifurcata.
12. Syringopora filiformis?
13. Syringopora caespitosa.
14. 14a. 14b. Catenipora escharoides.

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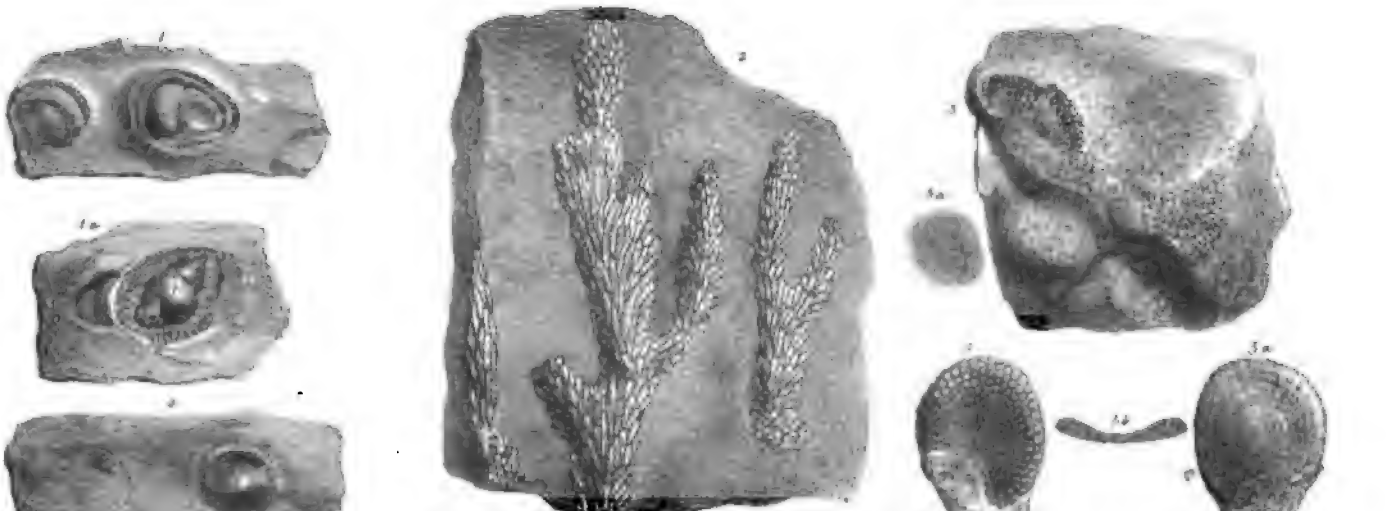
CORALS



WENLOCK ROCKS.

CORALS

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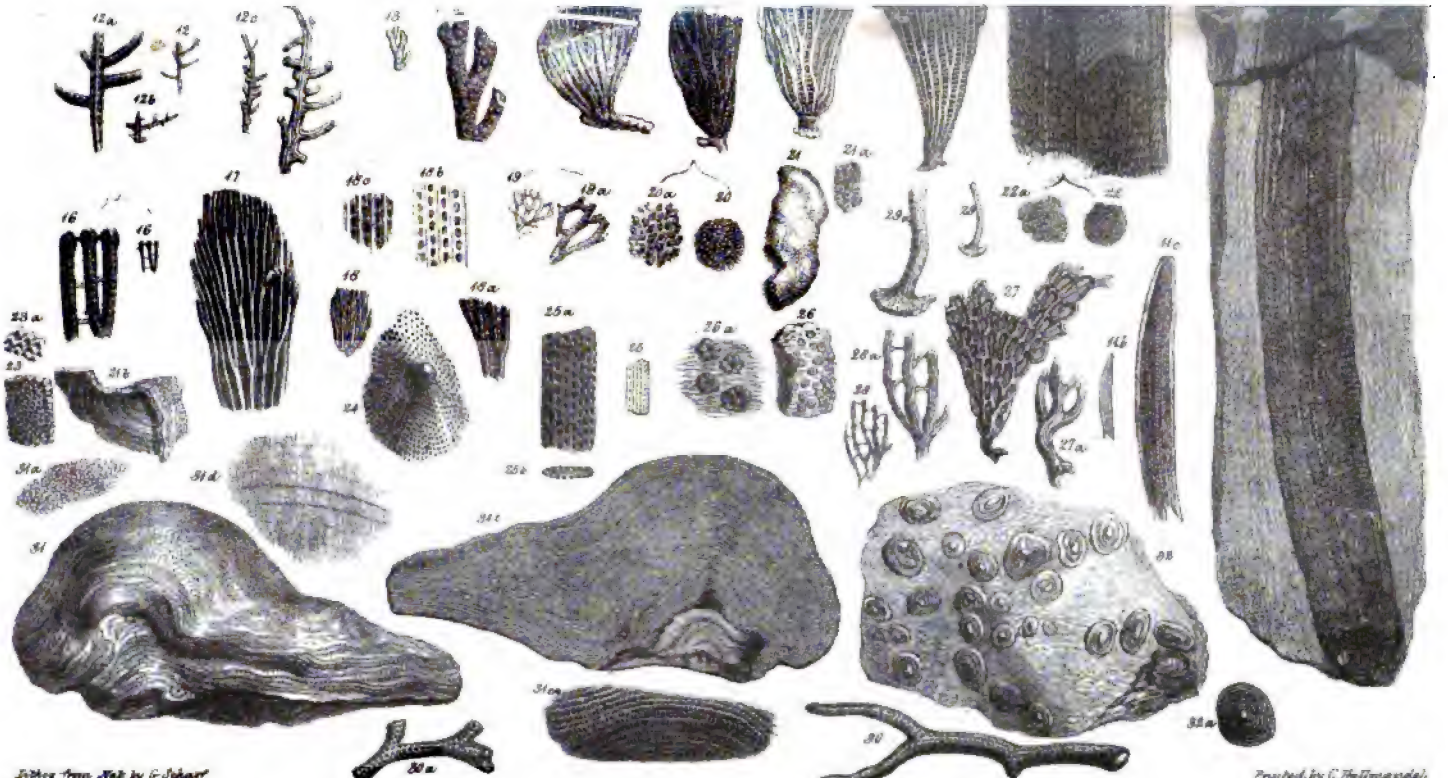

1. 1a. Alveolites fibrosa.
2. Favosites polymorpha.
3. 3a. Porites expatiata.
4. Cyclolites praecaita.
5. 5a. 5b. C. lenticulata.
6. Aulopora serpens.
7. A. consimilis.
8. [illegible]
9. Aulopora conglomerata.
10. Escharina ? angularis.
11. 11a. to 11c. Palodictya lanceolata.
12. 12a. to 12d. Glauconome desticha.
13. 13a. Hornera crassa.
14. 14a. Retepora crassa.
15. 15a. to 15c. 16. 16a. to 16c. Fenestella prisca.
17. Fenestella Müller.
19. 19a. F. reticulata.
20. 20a. Berenicea irregularis.
21. 21a. 21b. Discopora antiqua.
22. 22a. D. ? favosa.
23. 23a. D. squamata.
24. Retepora infundibulum.
25. 25a. Blumenbachium globosum ?
27. 27a. Gorgonia assimilis.
28. 28a. Gorgonia ?
29. 29a. Ceriopora granulosa.
30. 30a. Millepora repens.
31. 31a. to 31d. Stromatopora concentrica.
32. 32a. S. nummulitissimilis.

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PLATE XLI.

(Pl. 15 'Sil. Syst.')

Fig. 1, 1*a*. STENOPORA FIBROSA, Goldf. (var. INCRUSTANS, M'Coy.) Upper Ludlow rock. (ALVEOLITES FIBROSA.) Ludlow, Malvern, &c. This variety is always found encasing spiral shells, especially Cyclonema corallii and Murchisonia corallii.

2. FAVOSITES CRISTATA, Blumenb. (POLYMORPHA.) Wenlock and Ludlow rocks. Wenlock, Aymestry.

3. THECIA SWINDERNANA, Goldf. (PORITES EXPATIATA.) W.L. Benthall Edge, Wenlock, &c. A.L. Aymestry. 3*a*. Stars magnified.

4, 5. PALÆOCYCLUS PRÆACUTUS, Lonsd. (CYCLOLITES PRÆACUTA and C. LENTICULATA.) Wenlock rocks (bottom beds). Marloes Bay, Pembrokeshire. 4, 5. Under surface. 5*a*. Upper surface. 5*b*. Section.

6. SYRINGOPORA SERPENS, Linn. (AULOPORA.) The creeping base. Upper Llandovery, Prolimoor and Norbury. W.L. Lincoln Hill, Woolhope, Dudley, &c.

7. ——— (DIASTOPORA?) CONSIMILIS, Lonsd. (AULOPORA.) W.L. Dudley. Probably a Bryozoon. Figure twice magnified.

8. S. FASCICULARIS, Linn. (AULOPORA TUBÆFORMIS.) The creeping basal portion. W.L. Benthall Edge.

9. S. SERPENS, Linn. (AULOPORA CONGLOMERATA.) W.L. Dudley.

BRYOZOA.

[The following species, formerly included as a peculiar group in the Zoophyta, and therefore grouped by Mr. Lonsdale in this one plate, belong to the Mollusca Bryozoa.]

10. ESCHARINA? ANGULARIS, Lonsd. W.L. Dudley.

11. PTILODICTYA LANCEOLATA, Goldf. W.L. Malvern Hills. 11*a*. Magnified. 11*b*. Young specimen. 11*c*. The same magnified.

12. GLAUCONOME DISTICHA, Goldf. W.L. Wenlock, Dudley, &c. N. Wales in Caradoc rocks. 12*b*. Magnified. 12*c*, *d*. Striated surface, nat. size and magnified.

13. POLYPORA? CRASSA, Lonsd. (HORNERA.) W.L. Dudley. 13*a*. Cellular surface magnified three times.

14. HETEROPORA? CRASSA, Lonsd. W.L. Benthall Edge. 14*a*. Magnified.

15. FENESTELLA LONSDALEI, d'Orb. (PRISCA.) W.L. Dudley. 15*a*–15*c*. Nat. size and magnified.

16. F. SUBANTIQUA, d'Orb. (ANTIQUA.) W.L. Dudley. Also Caradoc sandstone. Natural size and magnified.

17. F. MILLERI, Lonsd. W.L. Dudley. Magnified about five times: the nat. size is omitted in the plate.

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Fig. 18. FENESTELLA LONSDALEI, d'Orb. As above.

19. F. RETICULATA, Lonsd. W.L. Dudley. Nat. size and magnified.

20. DIASTOPORA? IRREGULARIS, Lonsd. (BERENICEA.) W.L. Dudley. Nat. size and magnified.

21. DISCOPORA ANTIQUA, M.-Edw. W.L. Dudley. 21*a*. Upper surface, worn; nat. size and magnified. 21*b*. Upper and under surface; nat. size.

22. D.? FAVOSA, Lonsd. W.L. Dudley. Nat. size and magnified twice.

23. D. SQUAMATA, Lonsd. W.L. Dudley; Hurst Hill, Sedgley. 23*a*. Magnified.

24. PHYLLOPORA? INFUNDIBULUM, Lonsd. (RETEPORA.) W.L. Dudley.

25. PTILODICTYA SCALPELLUM, Lonsd. (ESCHARA.) W.L. Dudley, Woolhope, Malverns, &c. Nat. size and magnified; and 25*b*, section.

26. ————? (BLUMENBACHIUM GLOBOSUM, König?) W.L. Dudley. This curious specimen may be only an efflorescence of muriate of lime, gypsum, or some other salt upon the surface, the specimen having been subjected to acid.

27. FENESTELLA ASSIMILIS, Lonsd. (GORGONIA.) W.L. Dudley. 27*a*. Magnified.

28. FENESTELLA, sp. (GORGONIA?) W.Sh. Alfrick, Malverns.

29. CERIOPORA GRANULOSA, Goldf. W.L. Dudley, Ledbury. 29*a*. Magnified.

[The following species is a true Coral.]

30. ALVEOLITES? REPENS, Linn. (MILLEPORA.) W.L. Benthall Edge, Dudley, &c. Nat. size.

AMORPHOZOA (SPONGES).

31. STROMATOPORA STRIATELLA, d'Orb. (CONCENTRICA.) W.L. Dudley, Benthall Edge, Ledbury, &c. Also in W. Shale, Llandovery, and Caradoc rocks. A species distinct from the S. CONCENTRICA of the Devonian rocks. 31. Natural size. 31*a*. Surface magnified. 31*b*. Section, natural size, showing the concentric close layers. 31*c*. The same magnified.

32. ————? (S. NUMMULITISIMILIS, Lonsd.) W.L. Crews Hill, near Alfrick; and Mathen Lodge, Malvern. This is not a Stromatopora, but a specimen of very large-grained oolitic limestone. (See Phillips, Memoirs Geol. Surv. vol. ii. pt. 1. p. 78.)

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